LAN
824

HARVARD UNIVERSITY

Library of the
Museum of
Comparative Zoology

The CANADIAN FIELD-NATURALIST

MCZ LIBRARY
JUL 2 5 1993
HARVARD UNIVERSITY

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 106, Number 1

January-March 1992

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency The Right Honourable Ramon John Hnatyshyn, P.C., C.C., C.M.M., Q.C.,
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Edward L. Bousfield
Irwin M. Brodo
William J. Cody
William G. Dore
R. Yorke Edwards
Anthony J. Erskine
Clarence Frankton
Claude E. Garton
W. Earl Godfrey
C. Stuart Houston
Louise de K. Lawrence
Thomas H. Manning
Don E. McAllister
Stewart D. MacDonald
Verna Ross McGiffin
Hue N. MacKenzie
Eugene G. Munroe
Robert W. Nero
Hugh M. Raup
Loris S. Russell
Douglas B.O. Savile
Pauline Snure
Mary E. Stuart
Sheila Thomson

1992 Council

President: Frank Pope
Vice-President: Michael Murphy
Recording Secretary: Connie Clark
Corresponding Secretary: Eileen Evans
Treasurer: Gillian Marston

Ronald E. Bedford
Barry Bendell
Fenja Brodo
Steve Blight
Lee Cairnie
Martha Camfield
William J. Cody
Francis R. Cook
Don Cuddy
Ellaine Dickson
Enid Frankton
Colin Gaskell
Bill Gummer
Jeff Harrison
Linda Maltby
Jack Romanow
Doreen Watler
Ken Young

Those wishing to communicate with the Club should address correspondence to: The Ottawa Field-Naturalists' Club, Box 3264, Postal Station C, Ottawa, Canada K1Y 4J5. For information on Club activities telephone (613) 722-3050.

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Editor: Francis R. Cook, R.R. 3, North Augusta, Ontario K0G 1R0; 613-269-3211
Assistant to Editor: P.J. Narraway; **Copy Editor:** Wanda J. Cook
Business Manager: William J. Cody, Box 3264, Postal Station C, Ottawa, Ontario K1Y 4J5 (613) 996-1665
Book Review Editor: Dr. J. Wilson Eedy, R.R. 1, Moffat, Ontario L0P 1J0
Coordinator, *The Biological Flora of Canada*: Dr. George H. La Roi, Department of Botany, University of Alberta, Edmonton, Alberta T6G 2E9
Associate Editors:

C.D. Bird
Robert R. Campbell
Brian W. Coad
Anthony J. Erskine
W. Earl Godfrey
Diana Laubitz
William O. Pruitt, Jr.
Stephen M. Smith

Chairman, Publications Committee: Ronald E. Bedford

All manuscripts intended for publication should be addressed to the Editor at home address.

Subscriptions and Membership
Subscription rates for individuals are $23 per calendar year. Libraries and other institutions may subscribe at the rate of $38 per year (volume). The Ottawa Field-Naturalists' Club annual membership fee of $23 includes a subscription to *The Canadian Field-Naturalist.* All foreign subscribers (including USA) must add an additional $4.00 to cover postage. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be mailed to: The Ottawa Field-Naturalists' Club, Box 3264, Postal Station C, Ottawa, Canada K1Y4J5.
Second Class Mail Registration No. 0527 – Return Postage Guaranteed. Date of this issue: January-March 1992 (December 1992).

Back Numbers and Index
Most back numbers of this journal and its predecessors, Transactions of The Ottawa Field-Naturalists' Club, 1879-1886, and The Ottawa Naturalist, 1887-1919, and Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: Left: Portion of Hog's Back prairie and savanna, a remnant of the Rice Lake Plains near Alderville, Ontario. Right: Wild Lupine, *Lupinus perennis*, a rare species in Ontario, once abundant on the Rice Lake Plains, this plant part of a relict population near Harwood, Ontario. Photos by P. M. Catling. See article by P. M. Catling, V. R. Catling and S. M. McKay-Kuja on the Extent and Floristic Composition of the Rice Lake Plains, pages 73–86.

MCZ
LIBRARY
JAN 25 1993
HARVARD
UNIVERSITY

THE CANADIAN FIELD-NATURALIST

Volume 106

1992

THE OTTAWA FIELD-NATURALISTS' CLUB

OTTAWA CANADA

The Canadian Field-Naturalist

Volume 106, Number 1 January–March 1992

Rare and Endangered Fishes and Marine Mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports VIII.

R. R. CAMPBELL

Department of Fisheries and Oceans, 200 Kent Street, Ottawa, Ontario K1A 0E6
Present address: Administrator, Convention on International Trade in Endangered Species, Canadian Wildlife Service, Ottawa, Ontario K1A 0H3

Campbell R. R. *Editor*. 1992. Rare and endangered fish and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports VIII. Canadian Field-Naturalist 106(1): 1–6.

Eight status reports representing those species of fish and marine mammals which were assigned status at the 1991 COSEWIC General Meeting have been prepared for publication. Committee and Subcommittee (Fish and Marine Mammal) activities are briefly discussed. Updated lists of status assignments for fish and marine mammals and for species which are currently under consideration or yet to be considered are presented in tabular form.

Huit rapports sur le statut des poissons et des mammifères marins auxquells un statut a été attribué à la réunion du CSEMDC en 1991 ont été préparés pour publication. Les activités du Comité et du sous-comité (poissons et mammifères marins) sont brièvement discutées. Les listes à jour des espèces de poissons et de mammifères marins sur lesquelles déjà on a statées, ainsi que les sont présentées sous forme tabulaire.

Key Words: Rare and Endangered species, fish, marine mammals, COSEWIC.

As indicated in previous submissions (Campbell 1984-1991), the intent of the Subcommittee on Fish and Marine Mammals is to publish the status reports (on those species of fish and marine mammals) which the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has reviewed, approved, and used as a basis for the assignment of status to species in jeopardy in Canada. The group of eight reports presented herein represent the fish and marine mammal component of those species assigned status in 1991. It is hoped that we will have the continuing support of the Department of Fisheries and Oceans to offer, in succeeding volumes, those reports reviewed in future years (Table 1 presents those species assigned status to April 1991).

Progress

COSEWIC has undertaken to make public, supporting information on each species classified (*see* Cook and Muir 1984). The Fish and Marine Mammal Subcommittee has been able to use this journal as one step in achieving the goal [*see* Canadian Field-Naturalist 98(1): 63–133; 99(3): 404–450; 102(1): 81–176, 102(2): 270–398; 103(2): 147–220; 104(1): 1–138; 105(2): 151–293] and the encouraging response to these publications has enabled us to continue.

Contributions to the Committee of $10 000 made by the Department of Fisheries and Oceans and Environment Canada in 1990 were once again matched by World Wildlife Fund Canada. These permitted the contracting of several (12) new reports in 1990. Although there are a considerable number of reports in preparation or under review, the number of species still awaiting consideration has been reduced to three (Table 3) and contracts are being prepared for the production of reports on these.

There are currently 41 status reports on fish species and 15 on marine mammal species under review or in preparation (Table 2), several will be assigned status in 1992. In addition to soliciting further status reports on species of concern, the Subcommittee continues to obtain updated reports on the status of selected species as new information becomes available.

As a result of the addition of the Harbour Porpoise to the threatened list, the Department of Fisheries and Oceans has initiated efforts for the conservation of the species. A recovery team has been established and a recovery plan for the stocks in, at least, the Canadian portion of the range should soon be available. Team membership includes rep-

TABLE 1. Fish and Marine Mammal Species with Assigned COSEWIC Status to April 1991.

Species	Scientific Name	Status	Date Assigned
Fish			
Lake Sturgeon	*Acipenser fulescens*	RANSDR[a]	April 1986
Bloater	*Coregonus hoyi*	RANSDR	April 1988
Blueback Herring	*Alosa aestivalis*	RANSDR	April 1980
Hornyhead Chub	*Nocomis biguttatus*	RANSDR	April 1988
River Chub	*Nocomis micropogon*	RANSDR	April 1988
Redfin Shiner	*Lythrurus umbratilis*	RANSDR	April 1988
Leopard Dace	*Rhinichthys falcatus*	RANSDR	April 1990
Golden Redhorse	*Moxostoma erythrurum*	RANSDR	April 1989
Mountain Sucker	*Castostomus platyrhynchus*	RANSDR	April 1991
Least Darter	*Etheostoma microperca*	RANSDR	April 1989
River Darter	*Percina shumardi*	RANSDR	April 1989
Green Sunfish	*Lepomis cyanellus*	RANSDR	April 1987
Longear Sunfish	*Lepomis megalotis*	RANSDR	April 1987
Spoonhead Sculpin	*Cottus ricei*	RANSDR	April 1989
Brook Silverside	*Labidesthes sicculus*	RANSDR	April 1989
Y-Prickleback	*Allolumpenus hypochromus*	RANSDR	April 1991
Darktail Lamprey	*Lethenteron alaskense*	RAISIFSD[b]	April 1990
Bering Cisco	*Coregonus laurettae*	RAISIFSD	April 1991
Pixie Poacher*	*Occella impi*	RAISIFSD	April 1991
Vancouver Lamprey[c]	*Lampetra macrostoma*	Vulnerable[d]	April 1986
Chestnut Lamprey	*Ichthyomyzon castaneus*	Vulnerable	April 1991
Northern Brook Lamprey	*Ichthyomyzon fossor*	Vulnerable	April 1991
Green Sturgeon	*Acipenser medirostris*	Vulnerable	April 1987
Shortnose Sturgeon	*Acipenser brevirostrum*	Vulnerable	April 1980
White Sturgeon	*Acipenser transmontanus*	Vulnerable	April 1990
Spotted Gar	*Lepisosteus ocultus*	Vulnerable	April 1983
Kiyi	*Coregonus kiyi*	Vulnerable	April 1987
Squanga Whitefish[c]	*Coregonus* sp.	Vulnerable	April 1988
Pacific Sardine	*Sardinops sagax*	Vulnerable	April 1987
Silver Chub	*Macrhybopsis storeriana*	Vulnerable	April 1985
Umatilla Dace	*Rhinichthys umatilla*	Vulnerable	April 1988
Bigmouth Shiner	*Notropis dorsalis*	Vulnerable	April 1985
Pugnose Shiner	*Notropis anogenus*	Vulnerable	April 1985
Silver Shiner	*Notropis photogenis*	Vulnerable	April 1983[e]
Pugnose Minnow	*Opsepocodus emiliae*	Vulnerable	April 1985
Redside Dace	*Clinostomus elongatus*	Vulnerable	April 1987
Speckled Dace	*Rhinichthys osculus*	Vulnerable	April 1980[f]
Central Stoneroller	*Campostoma anomalum*	Vulnerable	April 1985
Banded Killifish (Newfoundland)	*Fundulus diaphanus*	Vulnerable	April 1989
Blackstripe Topminnow	*Fundulus notatus*	Vulnerable	April 1985
Bigmouth Buffalo	*Ictiobus cyprinellus*	Vulnerable	April 1989
Black Buffalo	*Ictiobus niger*	Vulnerable	April 1989
Spotted Sucker	*Minytrema melanops*	Vulnerable	April 1983
River Redhorse	*Moxostoma carinatum*	Vulnerable	April 1983[e]
Greenside Darter	*Etheostoma blennioides*	Vulnerable	April 1990
Brindled Madtom	*Notorus miurus*	Vulnerable	April 1985
Orangespotted Sunfish	*Lepomis humilus*	Vulnerable	April 1989
Redbreast Sunfish	*Lepomis auritus*	Vulnerable	April 1989
Fourhorn Sculpin (Arctic Islands)	*Myoxocephalus quadricornis*	Vulnerable	April 1989
Giant Stickleback[c]	*Gasterosteus* sp.	Vulnerable	April 1980
Unarmoured Stickleback[c]	*Gasterosteus* sp.	Vulnerable	April 1983
Blackline Prickleback	*Acantholumpenus mackayi*	Vulnerable	April 1989
Bering Wolffish	*Anarichus orientalis*	Vulnerable	April 1989
Lake Simcoe Whitefish[c]	*Coregonus clupeaformis* spp.	Threatened	April 1987
Blackfin Cisco	*Coregonus nigripinnis*	Threatened	April 1988
Shortnose Cisco	*Coregonus reighardi*	Threatened	April 1987
Shortjaw Cisco	*Coregonus zenithicus*	Threatened	April 1987
Deepwater Sculpin (Great Lakes Watershed)	*Myoxocephalus thompsoni*	Threatened	April 1987
Black Redhorse	*Moxostoma dusquesnei*	Threatened	April 1988

Continued

TABLE 1. *Concluded*

Species	Scientific Name	Status	Date Assigned
Copper Redhorse[c]	*Moxostoma hubbsi*	Threatened	April 1987
Margined Madtom	*Noturus insignis*	Threatened	April 1989
Enos Lake Stickleback[c]	*Gasterosteus* sp.	Threatened	April 1988
Shorthead Sculpin	*Cottus confusus*	Threatened	November 1983
Aurora Trout[c]	*Salvelinus fontinalis timagamiensis*	Endangered	April 1987
Acadian Whitefish[c]	*Coregonus huntsmani*	Endangered	April 1983
Salish Sucker	*Catostmus* sp.	Endangered	April 1986
Gravel Club	*Erimystax x-punctata*	Extirpated	April 1987[g]
Paddlefish	*Polyodon spathula*	Extirpated	April 1987
Deepwater Cisco	*Coregonus johannae*	Extinct	April 1988
Longjaw Cisco	*Coregonus alpenae*	Extinct	April 1988
Banff Longnose Dace[c]	*Rhinichthys cataractae smithi*	Extinct	April 1987
Blue Walleye	*Stizostedion vitreum glaucum*	Extinct	April 1985
Marine Molluscs			
Northern Abalone	*Haliotis kamtschatkana*	N/A[h]	April 1988
Marine Mammals			
California Sea Lion	*Zalophus californianus*	RANSDR	April 1987
Steller Sea Lion	*Eumetopias jubatus*	RANSDR	April 1987
Atlantic Walrus	*Odobenus rosmarus rosmarus*		
Eastern Arctic		RANSDR	April 1987
Northwest Atlantic		Extirpated	April 1987
Grey Whale	*Eschrichtius robustus*		
Northeast Pacific		RANSDR	April 1987
Northwest Atlantic		Extirpated	April 1987
Hooded Seal	*Cystophora cristata*	RANSDR	April 1986
Northern Elephant Seal	*Mirounga angustirostris*	RANSDR	April 1986
Ringed Seal	*Phoca hispida*	RANSDR	April 1989
Risso's Dolphin	*Grampus griseus*	RANSDR	April 1990
Northern Right Whale	*Lissodelphis borealis*	RANSDR	April 1990
Pacific White-sided Dolphin	*Lagenorhynchus obliquidens*	RANSDR	April 1990
Dall's Porpoise	*Phocoenoides dalli*	RANSDR	April 1989
Narwhal	*Monodon monoceros*	RANSDR	April 1986[e]
Blainville's Beaked Whale	*Mesoplodon densirostris*	RANSDR	April 1989
Cuvier's Beaked Whale	*Ziphius cavirostris*	RANSDR	April 1990
Hubb's Beaked Whale	*Mesoplodon carlhubbsi*	RANSDR	April 1989
Stejneger's Beaked Whale	*Mesoplodon stejnegeri*	RANSDR	April 1989
True's Beaked Whale	*Mesoplodon mirus*	RANSDR	April 1989
False Killer Whale	*Pseudorca crassidens*	RANSDR	April 1990
Atlantic White-sided Dolphin	*Lagenorhynchus acutus*	RANSDR	April 1991
Common Dolphin	*Delphinus delphis*	RANSDR	April 1991
Beluga	*Delphinapterus leucas*		
Beaufort Sea		RANSDR	April 1986
St. Lawrence River		Endangered	April 1983
Eastern Hudson Bay		Threatened	April 1988
Ungava Bay		Endangered	April 1988
S.E. Baffin Island		Endangered	April 1990
Sowerby's Beaked Whale	*Mesoplodon bidens*	Vulnerable	April 1989
Blue Whale	*Balaenoptera musculus*	Vulnerable	April 1983
Fin Whale	*Balaenoptera physalus*	Vulnerable	April 1987[f]
Sea Otter	*Enydra lutris*	Endangered	May 1978[i]
Harbour Porpoise	*Phocoena phocoena*		
Northwest Pacific		RAISIFSD	April 1991
Northeast Atlantic		Threatened	April 1990
Humpback Whale	*Megaptera novaeangliae*		
Northeast Pacific		Threatened	April 1982[j]
Northwest Atlantic		Vulnerable	April 1985
Bowhead Whale	*Balaena mysticetus*	Endangered	April 1980[i]
Right Whale	*Eubalaena glacialis*	Endangered	April 1980[k]
Sea Mink	*Mustela macrodon*	Extinct	April 1985

[a] RANSDR — Use of NIAC (Not in Any Category) dropped in 1988 and subsequently converted. RANSDR is not a category = Report Accepted No Status Designation Required.
[b] RAISIFSD — the use of a new list "Report Accepted Insufficient Scientific Information For Status Designation" was approved at the 1990 General Meeting.
[c] Endemic to Canada
[d] Vulnerable — "Rare" category changed to "Vulnerable" in 1988. Dates Assigned of 1988 or earlier indicate date of original Rare status assignment. These were subsequently converted to Vulnerable at the 1990 General Meeting based on the advice of the Fish and Marine Mammal Subcommittee.
[e] Updated April 1987 — no status change.
[f] Updated April 1984 — no status change.
[g] Updated April 1987 — previous status of "Endangered" assigned April 1985.
[h] N/A — Status Not Assigned. COSEWIC has no mandate for invertebrates. Report accepted and recommended RANSDR Status agreed to, but not assigned.
[i] Updated April 1986 — no status change.
[j] Updated April 1985 — North Atlantic stock downlisted to 'Vulnerable'
[k] Updated April 1985 and April 1990 — no status change.

TABLE 2. Fish and Marine Mammal Species for which Status Reports are in preparation, or under review, April 1991

Species	Scientific Name	Proposed Status
Fish		
Atlantic Sturgeon	*Acipenser oxyrhynchus*	?
Lake Sturgeon°	*Acipenser fulvescens*	?
Red (Arctic) Char[1]	*Salvelinus alpinus* spp.	? (Landlocked populations: Quebec, New Brunswick, Newfoundland
Atlantic Salmon	*Salmo salar*	?
Bull Trout	*Salvelinus confluentus*	Vulnerable
Spring Cisco*	*Coregonus* sp.	?
Lake Herring	*Coregonus artedi*	Endangered — Lakes Erie, Ontario
Lake Whitefish	*Coregonus clupeaformis*	Threatened — Lakes Erie, Ontario
Mira Whitefish	*Coregonus* sp.	Vulnerable
Opeongo Whitefish*	*Coregonus* sp.	Threatened
Round Whitefish	*Prosopium cylindraceum*	Vulnerable — Lakes Huron, Ontario
Pygmy Whitefish	*Prosopium coulteri*	?
Pygmy Smelt	*Osmerus spectrum*	Vulnerable
Chain Pickerel	*Esox niger*	Vulnerable
Grass Pickerel	*Esox americanus vermiculatus*	Vulnerable
Redfin Pickerel	*Esox americanus americanus*	Vulnerable
Blackchin Shiner	*Notropis heterodon*	Vulnerable
Bluntnose Minnow	*Pimphales notatus*	Vulnerable (Manitoba)
Chiselmouth	*Acrocheilus alutaceus*	Vulnerable (British Columbia)
Cutlips Minnow	*Exoglossum maxillingua*	Vulnerable
Eastern Silvery Minnow	*Hybognathus nuchalis regius*	Vulnerable
Ghost Shiner	*Notropis buchanani*	Vulnerable
Roseyface Shiner	*Notropis rubellus*	Vulnerable
Striped Shiner	*Luxilus chrysocephalus*	Vulnerable
Weed Shiner	*Notropis texanus*	Vulnerable (Manitoba)
Western Silvery Minnow	*Hybognathus argyritis*	? (Alberta)
Lake Chubsucker	*Erimyzon sucetta*	Vulnerable
Jasper Longnose Sucker*	*Castostomus castostomus lacustris*	Vulnerable
Warmouth	*Lepomis gulosus*	Vulnerable
Striped Bass	*Morone saxatilis*	Endangered
Channel Darter	*Percina copelandi*	Vulnerable
Eastern Sand Darter	*Ammocrypta pellucida*	Vulnerable
Tessellated Darter	*Etheostoma olmstedi*	Vulnerable
Flathead Catfish	*Pylodictis olivaris*	?
Northern Madtom	*Noturus stigmosus*	Vulnerable

Continued

TABLE 2. *Concluded*

Species	Scientific Name	Proposed Status
Texada Stickleback*	*Gasterosteus* sp	Vulnerable
Cultus Pygmy Coastrange Sculpin•	*Cottus aleuticus*	Threatened (British Columbia)
Mottled Sculpin	*Cottus bairdi*	Vulnerable (British Columbia, Alberta)
Shorthead Sculpin°	*Cottus confusus*	Vulnerable
Spinynose Sculpin	*Asemichthys taylori*	Vulnerable
Bluefin Tuna	*Thunnus thynnus*	?
Marine Mammals		
White-beaked Dolphin	*Lagenorhynchus albirostris*	?
Baird's Beaked Whale	*Berardius bairdii*	?
Beluga Whale (W. Hudson Bay)	*Delphinapterus leucas*	
Northern Bottlenose Whale	*Hyperoodon ampullatus*	?
Bowhead Whale°	*Balaena mysticetus*	Endangered
Killer Whale	*Orcinus orca*	?
Long-finned Pilot Whale	*Globicephela malaena*	?
Sperm Whale	*Physeter catadon*	?
Striped Dolphin	*Stenella coeruleoalba*	?
Bottlenose Dolphin	*Tursiops truncatus*	?
Short-finned Pilot Whale	*Globicephala macrorhynchus*	Vulnerable
Pygmy Sperm Whale	*Kogia breviceps*	Vulnerable
Sei Whale	*Balaenoptera borealis*	?
Minke Whale	*Balaenoptera acutorostrata*	?
Dwarf Sperm Whale	*Kogia simus*	Vulnerable

*Endemic to Canada °Updated Status Report [1]Not of immediate concern

TABLE 3. Fish and Marine Mammal Species of Interest to COSEWIC — April 1991 (Not listed by priority)

Species	Scientific Name	Proposed Status
Fish		
Pygmy Longfin Smelt*	*Spirinichus thaleichthys*	Vulnerable (landlocked population in Harrington Lake, British Columbia)
Nooky Dace	*Rhinichthys cataractae* spp.	Vulnerable (British Columbia)
Liard Hotspring Lake Chub*	*Couesius plumbeus* spp.	Vulnerable (British Columbia's Liard Hotspring)

*Endemic to Canada

resentation from the United States and there is no doubt that ultimately recovery plans should be international in character.

Acknowledgments

The Subcommittee wishes to extend their thanks to the various authors who have so generously contributed their time and talent in support of COSEWIC, and I wish also to thank the members of the Subcommittee for their unstinting efforts in reviewing the reports and for their helpful comments.

The Subcommittee is grateful to World Wildlife Fund Canada, the Canadian Wildlife Service, and the Canadian Museum of Nature (formerly the National Museum of Natural Sciences) for their assistance in the process. A special mention to Francis Cook and *The Canadian Field-Naturalist* for assistance in publication and editing, and to all members of COSEWIC for their dedication and interest in the future of Canada's fauna and flora. We also gratefully acknowledge the financial and secretarial support provided through the Department of Fisheries and Oceans and the financial contribution of Fisheries and Oceans, Environment Canada, and World Wildlife Fund Canada which has permitted the production of several new reports.

Literature Cited

Campbell, R. R. 1984. Rare and Endangered fish of Canada: The Committee on the Status of Endangered Wildlife in Canada: (COSEWIC) Fish and Marine Mammal Subcommittee. Canadian Field-Naturalist 98(1): 71–74.

Campbell, R. R. 1985. Rare and endangered fish and marine mammals of Canada: COSEWIC Fish and Marine Mammals Subcommittee Reports: II. Canadian Field-Naturalist 99(3): 404–408.

Campbell, R. R. 1987. Rare and endangered fish and marine mammals of Canada: COSEWIC Fish and Marine Mammals Subcommittee Reports: III. Canadian Field-Naturalist 101(2): 165–170.

Campbell, R. R. 1988. Rare and endangered fish and marine mammals of Canada: COSEWIC Fish and Marine Mammals Subcommittee Reports: IV. Canadian Field-Naturalist 102(1): 81–86.

Campbell, R. R. 1989. Rare and endangered fish and marine mammals of Canada: COSEWIC Fish and Marine Mammals Subcommittee Reports; V. Canadian Field-Naturalist 103(2): 147–157.

Campbell, R. R. 1990. Rare and endangered fish and marine mammals of Canada: COSEWIC Fish and Marine Mammals Subcommittee Reports: VI. Canadian-Field Naturalist 104(1): 1–6.

Campbell, R. R. 1991. Rare and endangered fish and marine mammals of Canada: COSEWIC Fish and Marine Mammals Subcommittee Reports: VII. Canadian Field-Naturalist 105(2): 151–156.

Cook, F. R., and **D. Muir.** 1984. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC): History and progress. Canadian Field-Naturalist 98(1): 63–70.

Reeves, R. R., and **E. Mitchell.** 1989. Status of White Whales (*Delphinapterus leucas*) in Ungava Bay and eastern Hudson Bay. Canadian Field-Naturalist 103(2): 220–239.

Accepted 31 May 1991

Status of the Northern Brook Lamprey, *Ichthyomyzon fossor*, in Canada*

J. LANTEIGNE

58-2069 Jasmine Crescent, Gloucester, Ontario K1J 7W2

Lanteigne, J. 1992. Status of the Northern Brook Lamprey, *Ichthyomyzon fossor,* in Canada. Canadian Field-Naturalist 106(1): 7–13.

The Northern Brook Lamprey, *Ichthyomyzon fossor*, is a small, non-parasitic lamprey not particularly abundant in its endemic North American range. In Canada, it is found in the Hudson Bay drainage of Manitoba and in the Great Lakes drainage of Ontario and Quebec. These represent the northern limits of its range. It has never been the object of a directed survey in Canada; its precise status is thus unknown. The Northern Brook Lamprey is not specifically protected in Canada except for the general protection granted through the fish protection and pollution prevention sections of the Fisheries Act. The paucity of Canadian records supports a status of vulnerable for this species.

De petite taille et non parasite, la lamproie du Nord, *Ichthyomyzon fossor*, n'est pas très abondante dans son aire de répartition limitée à l'Amérique du Nord. Au Canada, elle est présente dans le bassin hydrographique de la baie d'Hudson, au Manitoba, et dans le bassin hydrographique des Grands Lacs, au Québec et en Ontario. Ces coordonnées représentent les limites septentrionales de son aire de répartition. Étant donné qu'elle n'a jamais fait l'objet d'un relevé orienté au Canada, on n'y connaît pas sa situation exacte. Elle n'est pas protégée de façon précise dans les eaux canadiennes, sauf pour ce qui est d'une protection générale en vertu des articles sur la protection de l'habitat des poissons et de la prévention de la pollution de la Loi sur les pêches. Sa rare capture dans les eaux canadiennes indique que l'espèce est vulnérable.

Key Words: Petromyzontidae, lampreys, Northern Brook Lamprey, lamproie du Nord, *Ichthyomyzon fossor*, vulnerable fishes.

The Northern Brook Lamprey, *Ichthyomyzon fossor* Reighard and Cummins 1916, is a non-parasitic lamprey endemic to North America where it is restricted to tributaries of Hudson Bay, the Great Lakes and the Mississippi River (Lanteigne 1981). The six species which comprise the genus *Ichthyomyzon*, probably the most primitive among the Northern Hemisphere lampreys (Hubbs and Trautman 1937), can be grouped into three species pairs each composed of a parasitic stem species and a non-parasitic satellite species. Thus, *Ichthyomyzon fossor* is the non-parasitic derivative of the parasitic stem species, *Ichthyomyzon unicuspis*. After metamorphosis, the parasitic species feed mainly on teleost fishes for one or more years (Scott and Crossman 1973) while the non-parasitic species spawn soon after transformation. All lampreys die soon after spawning.

Description

The adult Northern Brook Lamprey can reach a total length of 161 mm [Royal Ontario Museum (ROM) 177687]; Hubbs and Trautman (1937) reported a range of 94 to 146 mm (average 119 mm) and Lanteigne (1981) gave a range of 98 to 158 mm. In the streams of Michigan's Lower Peninsula, which yielded a more homogeneous sample, Morman (1979) found a range of 86 to 166 mm (average 115 mm). The number of trunk myomeres usually varies from 51 to 54 (average 52) (Lanteigne 1981) even though Hubbs and Trautman report a smaller range of 50 to 52 (average 51). Its body is definitely bicoloured: the dark slate of the back and sides contrasts with the pale grey or silvery white lower parts (Vladykov 1949). The ventral surface is somewhat tinted with orange, which is particularly noticeable in the sexually mature female where the eggs show through the body wall (Leach 1940). The lateral line organs are non-pigmented, a characteristic which readily separates it from its parasitic stem species, *Ichthyomyzon unicuspis*, (Vladykov 1949). All the disc teeth are blunt and degenerate in keeping with its non-parasitic lifestyle which is also evident in the non-functional nature of its intestine. All the endolateral teeth, a diagnostic character, are unicuspid (Figure 1).

Distribution

In the drainage basins of the Eastern United States (Figure 2), the Northern Brook Lamprey is found in the Western Great Lakes basin of Wisconsin and Michigan, in the Eastern Great Lakes basin of

*Report accepted by COSEWIC and Vulnerable Status assigned 9 April 1991.

FIGURE 1. *Ichthyomyzon fossor:* female, 150 mm TL: Birch River, upstream of Prawda, Manitoba; May 13, 1977; J. Jyrkkanen; ROM 34264. Note blunt, degenerate and unicuspid disc teeth.

Michigan, Ohio and Pennsylvania (not present in Lake Ontario), in the Ohio basin of Illinois, Indiana, Ohio and Kentucky and in the Lower Missouri basin of Missouri where a disjunct population is found in the Ozark Uplands (Figure 3) [Pflieger 1971].

In Canada (Figure 4), the Northern Brook Lamprey occurs in the Great Lakes basin from Lake Superior to Lake Erie but appears to be absent in the Lake Ontario drainage (Scott and Crossman 1973) even though one transformed individual was captured in Tosorontio Creek (49°09'N, 79°58'W) in 1974 (ROM 30543). It has been captured in the Ottawa River at Ottawa (45°28'N, 75°37'W) [Canadian Museum of Nature (NMC) 82-0319] and it occurs in the St. Lawrence River down to the Nicolet River (Vladykov 1952). Its range in Canada has recently been extended further west to the Nelson River drainage of Manitoba (Jyrkkanen and Wright 1979) where it has been captured in the Whitemouth River (50°00'N, 96°00'W) and one of its tributaries, the Birch River (49°39'N, 95°47'W). This distribution represents the northern limits of the range of the Northern Brook Lamprey in North America.

Protection

The Northern Brook Lamprey is not listed as endangered, threatened or of concern in North America (Williams et al. 1989). In Canada, the species is not the object of any specific legal protection other than the general protection granted under habitat and pollution prevention sections of the Federal Fisheries Act. In Manitoba protection can be afforded through the provincial Endangered Species Act by regulation.

Population Sizes and Trends

No population estimates are available. In the St. Lawrence drainage of Quebec, Vladykov (1952) captured 63 adults and 849 ammocoetes between September 1946 and August 1951. The range extension of the species to Manitoba concerned 14 adult specimens (Jyrkkanen and Wright 1979). Collection records from the Royal Ontario Museum and the Canadian Museum of Nature reveal the paucity of specimens from the Great Lakes drainage as well as from other Canadian localities. It was formerly present in the Lake Ontario watershed but is now absent, or considered to be extremely rare. It is possibly present in a few scattered tributary creeks (Crossman and van Meter 1979) as in Tosorontio Creek. There is no indication that the species is in

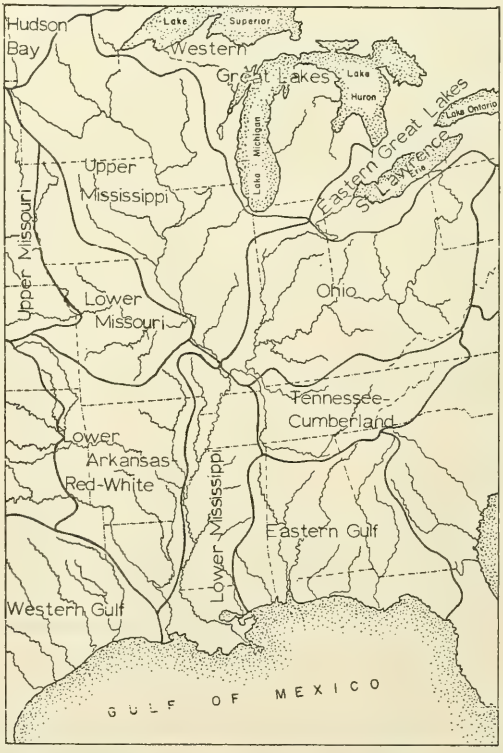


FIGURE 2. Principal drainage basins of the Eastern United States where the genus *Ichthyomyzon* is found.

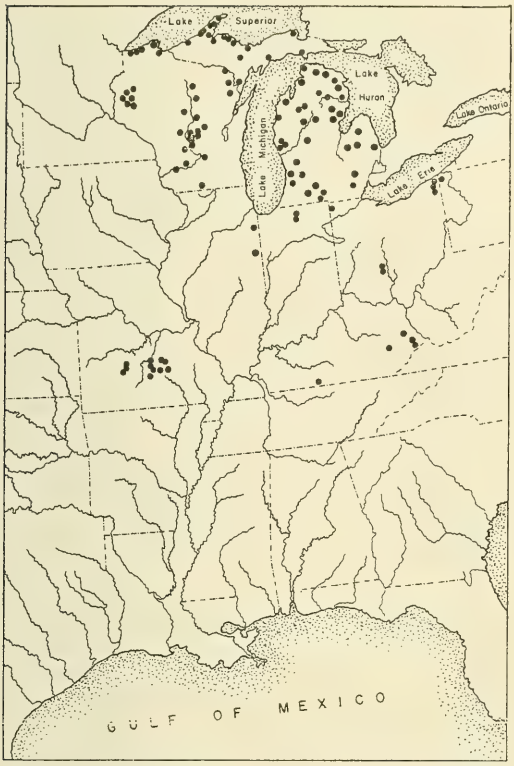


FIGURE 3. Distributional records of *Ichthyomyzon fossor* in Eastern United States.

danger of extinction but the state of our knowledge is such that no predictions can be made. The better fish sampling methods used in the last two or three decades, as well as the major research effort expanded in the Great Lakes in the wake of the sea lamprey invasion, may be in part responsible for the greater number of endemic lampreys appearing in fish collections. This increase should, therefore, not be viewed as a real increase in abundance.

Habitat

The ammocoetes of the Northern Brook Lamprey require a fairly soft bottom in which to make their burrows; as a rule, they are not found in firm sand or in the extremely soft mud of backwaters (Churchill 1947). In a given area with suitable bottom, they are most numerous in water 15 to 61 cm deep, amongst the vegetation. Maximum silt content and total volatile organic content of occupied sediments in an Ohio creek were 77% and 65%, respectively (Anderson and White 1988). Small ammocoetes were less tolerant of silt than large ones. The highest density of ammocoetes are usually found in the warmer sections of streams and tributaries receiving large surface flow of warm water from lakes, swamps and marshes (Morman 1979).

In Quebec, adult Northern Brook Lampreys are found in brooks tributary to small rivers. In the Yamaska River, where it was most abundant at St. Césaire where the river spans from 30 to 130 m, the current was moderate, the water was turbid and the banks were composed of clay (Vladykov 1952). In the Lake Superior watershed, *Ichthyomyzon fossor* was most common in medium-to-large streams with average summer flows of 0.3 to 28.3 cubic meters per second (Schuldt and Goold 1980). It was also common in several turbid streams. Along the western half of the United States shoreline, the preferred streams were generally warmer than eastern streams. In the lower peninsula of Michigan, the Northern Brook Lamprey was rarely found in small stream systems; it was most frequently collected in small, isolated segments of moderate-sized to large streams characterized by summer low flows (Morman 1979). It typically lived in the warmer, less rapid lower reaches of streams and tributaries that received large surface flow of warm water from lakes, swamps or marshes. It was also less commonly found in cold-water environments where mean daily temperatures during mid-June to August ranged from 14° to 20°C. In Manitoba, *Ichthyomyzon fossor* has been collected in the Birch River, a tributary of the Winnipeg River (Jyrkkanen and Wright 1979). The Birch River is a small river with a maximum flow of 5.7 to 8.5 cubic meters per second (cm/s) and a low flow of less than 0.15 cm/s. The substrate is highly varied with silts and sediments in the quieter reaches of the stream, gravel and cobble riffles and several small waterfalls.

In the Yamaska River of Quebec, the Northern Brook Lamprey spawned in May when the water temperature ranged from 12.8° to 17.2°C. Spawning activity peaked at water temperatures of 13.3° to 15.6°C (Vladykov 1949). In Michigan, spawning activities were observed from 23 May to 27 May and were most vigorous at water temperatures ranging from 20° to 22°C; spawning seldom took place at water temperatures inferior to 18°C (Reighard and Cummins 1916). All the spawners were observed on a bottom of coarse gravel and shingle which contained stones from 2.5 to 15.2 cm in diameter, and in water from 20.3 to 45.7 cm deep. At that point, the stream was less than 10 m wide with a strong current (Reighard and Cummins 1916).

General Biology

Reproductive Capability

Like all lampreys, the Northern Brook Lamprey breeds only once. According to Leach (1940), the ammocoete period lasts six years and is followed by a short transformation period of two or three months and an immature adult period of a semi-sedentary nature. The latter lasts until mid-February. The active early adult period follows and leads to sexual

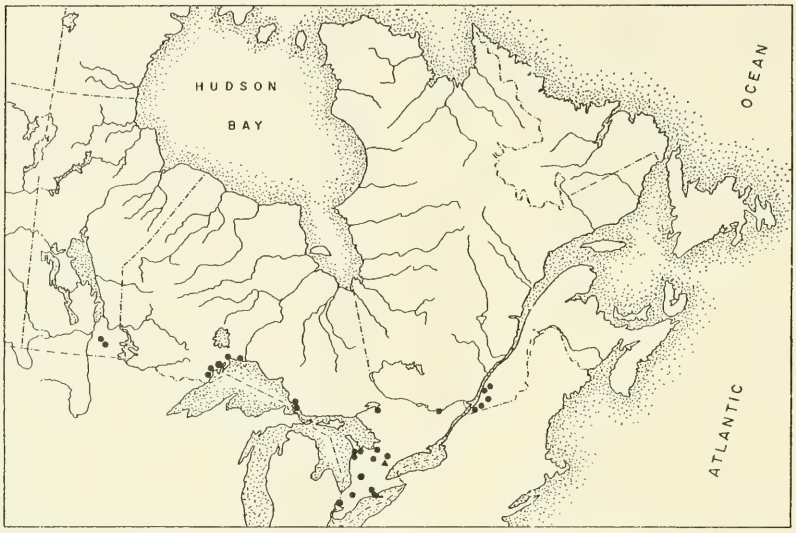


FIGURE 4. Distribution records of *Ichthyomyzon fossor* in Canada.

maturity around mid-May. The post-spawning period probably lasts only a few days, after which all spawners die. Since degeneration of the alimentary canal occurs at the beginning of transformation, there is a period of eight or nine months during which no food is taken (Churchill 1947).

Three physical factors in streams are essential for successful spawning: first, for nest building, a suitable substrate of gravel is required that includes at least a small amount of silt-free sand or other fine material to which the eggs can adhere, thereby increasing the probability of their retention in the nest. Second, a current must be flowing uni-directionally over the nest. Third, the water temperatures must be suitable.

In Manitoba, fourteen mature individuals were captured in the Birch River in mid-May 1977 (Jyrkkanen and Wright 1977). Of these, 10 were males and four were females. They were assumed to be spawning at the time of collection. No details on the reproductive behavior were reported. Two more sexually mature individuals, a male and a female whose eggs were free in the body cavity, were captured in the Whitemouth River (into which the Birch River empties) in mid-July 1977 (Lanteigne 1981). For two nests in which sex ratio was determined in a Michigan river, 11 males and two females were in one and three males and one female in the other (Morman 1979). In a tributary of southern Lake Superior, Purvis (1970) noted that 97% of the metamorphosed specimens collected in August were males and in June, 75% of the spawners were also males.

In a Michigan river, *Ichthyomyzon fossor* was observed in seven nests on 13 June when water temperatures ranged from 16.5° to 20.5°C (daily mean 18°C) [Morman 1979]. Spawning occurred in a shallow, pool-riffle, high-gradient stretch of the stream. Nests were inconspicuously located in interstices beneath large stones (18 to 36 cm in diameter) and were poorly defined. Spawners were unobtrusive as had been observed by Reighard and Cummins (1916).

The number of eggs laid is roughly in proportion to the size of the female. The actual fecundity of nine *Ichthyomyzon fossor* females from Quebec (128 to 150 mm TL) averaged 1524 eggs (range 1115 to 1979 eggs) (Vladykov 1951) whose average diameter was 1.01 mm. Leach (1940) recorded 780 eggs in a 92 mm TL ripe female. The eggs are demersal (Fuiman 1982) and seem to develop in an extremely adhesive glue-like mass under artificial conditions (Leach 1940) where the incubation period lasted 9 days at 18°C (Smith et al. 1968).

After fertilization, the eggs become covered by the substrate in and around the nests (Hardisty and Potter 1971). After hatching, the proammocoetes emerge from the substrate and drift downstream where they burrow into silt beds, especially along protected banks (Piavis 1971).

Behavior/Adaptability

The young larvae settle down into the soft bottom of slowly flowing waters where they are carried by the current. According to Sawyer (1959), the mouth is directed towards the current, with the upper section of the burrow sloping obliquely towards the mud surface. For several years, they lie concealed in the silt deposits, feeding on desmids, diatoms and protozoans (Scott and Crossman 1973) strained from the water. Since their burrows at the substrate sur-

face are sometimes closed off, food may be drawn from the sediments, depending on environmental conditions and activity of the ammocoetes (Moore and Mallatt 1980). In fact, detritus is frequently reported in the gut contents of all species of lampreys, although its relative abundance may vary with season and locality (Hardisty and Potter 1971).

Species Movement

It appears that ammocoete movement differs between streams owing probably to variations in such conditions as flow and bottom stability, current velocity, flooding and ammocoete density in relation to preferred habitat (Morman et al. 1980). Hardisty and Potter (1971) suggested that in some streams, particularly those with low gradients, stable flows and suitable habitats, the downstream migration of lamprey larvae is minimal. It appeared to Leach (1940) that ammocoetes moved only when the substrate was disturbed or when food was in short supply. Downstream migration takes place primarily at night; thus, predation by diurnal birds and mammals is minimal.

Limiting Factors

Lowering of water levels is probably a significant ammocoete mortality factor (Scott and Crossman 1973). Such is the case in the Yamaska River, where severe low water levels are regularly recorded in summer; these are generally followed by degradation of the aquatic environment (Mongeau et al. 1988). Siltation and pollution are a threat to successful spawning which requires a suitable substrate of clear gravel (Bailey 1959; Starrett et al. 1960). General deterioration in river habitat may reduce the available food supply of larvae and increasing levels of toxic chemicals may cause direct mortality.

Richards (1976) demonstrated a reduction in numbers of *Ichthyomyzon fossor* larvae and other warmwater fishes in a Michigan basin concurrent with the trend toward an increase in the relative abundance of coldwater species between the 1920s and 1972; he hypothesized that these changes were caused by a decrease in average water temperatures after that particular Michigan river basin was reforested and low-head impoundments were removed.

It is assumed that larval lampreys are largely immune from predation because of their burrowing sedentary habits (Churchill 1947; Hardisty and Potter 1971). However, evidence that ammocoetes are readily eaten by predatory fish is found in their formerly common and widespread use as bait (Vladykov 1949; Scott and Crossman 1973). In the course of field work carried out in the Ottawa River at Ottawa in the spring of 1979 and 1980, I observed unidentified predatory fishes capture ammocoetes swimming at the surface away from the electrical field generated by an electroshocker.

Lampreys on nests are probably most vulnerable to predators because they are more exposed in relatively shallow water and are not cautious. Therefore, in streams with few spawners, predators could reduce or prevent successful spawning (Morman et al. 1979).

Starting in 1958, Sea Lamprey (*Petromyzon marinus*) control programs in the upper three Great Lakes – Huron, Michigan and Superior – were carried out in Canadian and American streams with the help of a non-selective lampricide (Smith and Tibbles 1980). These programs were extended to Lake Ontario in 1971. In the process, native lampreys were inadvertently destroyed and their distribution throughout the Great Lakes watershed was greatly reduced. For example, 64% of the Lake Superior streams inhabited by native lampreys required treatment (Schuldt and Goold 1980). Lampricide was thus applied to 81 of the 105 streams inhabited by *Ichthyomyzon* larvae and the genus subsequently disappeared from 41 of the treated streams. They were readily eliminated from watersheds where they were confined to short stretches and where few sources of recruitment were available. Native lampreys disappeared from most streams unless they inhabited areas above barriers, in lentic environments, in tributaries in which Sea Lamprey did not spawn, or in difficult to treat areas such as oxbows, beaver ponds, long estuaries and springs. These changes reflect, in general, the results in the other Great Lakes where Sea Lamprey control programs were carried out.

Fecundity of a species is important in its recovery after lampricide treatment. In *Ichthyomyzon fossor*, fecundity was found to be twelve times less than its parasitic stem species, *Ichthyomyzon unicuspis* (Vladykov 1951). Its low fertility and mobility due to its non-parasitic nature suggest that it would be more vulnerable to chemical treatment than would parasitic lampreys.

Special Significance of the Species

All species, lampreys included, are part of our biodiversity heritage. While some may feel that all lampreys should be eradicated, it must be remembered that they are one of the oldest and most successful groups of living fishes (Beamish 1987). As such, they offer an excellent opportunity to study evolution in fishes and the reasons for their continued success in a changing environment. Even though the Northern Brook Lamprey has scientific interest, it is doubtful that the general public would support its protection.

Concern over the loss of non-parasitic lampreys was expressed by Vladykov (1973). According to him, a large concentration of ammocoetes in a brook is very favorable to its ecosystem. As prey of the Rainbow Trout (*Oncorhynchus mykiss*), Smallmouth Bass (*Micropterus dolomieui*), Grass Pickerel (*Esox*

americanus) [Vladykov 1949], American Eel (*Anguilla rostrata*) [Perlmutter 1951], Northern Pike (*Esox lucius*) [McPhail and Lindsey 1970] and Rock Bass (*Ambloplites rupestris*) [Hubbs and Trautman 1937], they represent an important link in the food chain. They also function as filter feeders and detritivores and so play a role in recycling dead organic matter into living tissue (Vladykov 1973).

Evaluation

Due to its restricted distribution in Canada, and eradication from some sites by the Sea Lamprey control program, the Northern Brook Lamprey can be considered a vulnerable species according to COSEWIC definitions. Its occurrence as disjunct populations and its affinity for areas of poor natural drainage and warmwater habitats suggest that this species may have been more abundant and widespread in an earlier period (Morman 1979).

Acknowledgments

Financial support for this report was provided through World Wildlife Fund Canada and the Department of Fisheries and Oceans Canada. Thanks are extended to the Royal Ontario Museum and the Canadian Museum of Nature for the provision of collection records. I also wish to acknowledge D. E. McAllister of the Canadian Museum of Nature for his helpful comments and review of the manuscript.

Literature Cited

Anderson, A. A., and **A. M. White**. 1988. Habitat selection of *Ichthyomyzon fossor* and *Lampetra appendix* in a north-eastern Ohio stream. Ohio Journal of Science 88(2): 7.

Bailey, R. M. 1959. Parasitic lampreys (*Ichthyomyzon*) from the Missouri River, Missouri and South Dakota. Copeia 1959(2): 162–163.

Beamish, R. J. 1987. Status of the lake lamprey, *Lampetra macrostoma*, in Canada. Canadian Field-Naturalist 101(2): 186–189.

Churchill, W. S. 1947. The brook lamprey in the Brule River. Transactions of the Wisconsin Academy of Sciences, Arts and Letters 37(1945): 337–346.

Crossman, E. J., and **H. D. van Meter.** 1979. Annotated list of the fishes of the Lake Ontario watershed. Great Lakes Fisheries Commission Technical Reports 36.

Fuiman, L. E. 1982. Family Petromyzontidae, Pages 23–37 *in* Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. *Edited by* N. A. Auer. Great Lakes Fisheries Commission Special Publication 82–3.

Hardisty, M. W., and **I. C. Potter.** 1971. The behaviour, ecology and growth of larval lampreys and the general biology of adult lampreys. Pages 85–125 *in* The biology of lampreys, Volume 1. Academic Press, London.

Hubbs, C. L., and **M. B. Trautman.** 1937. A revision of the lamprey genus *Ichthyomyzon*. Miscellaneous Publications of the Museum of Zoology, University of Michigan 35.

Jyrkkanen, J., and **D. G. Wright.** 1979. First record of the Northern Brook Lamprey, *Ichthyomyzon fossor*, in the Nelson River drainage, Manitoba. Canadian Field-Naturalist 93(2): 199–200.

Lanteigne, J. 1981. The taxonomy and distribution of the North American lamprey genus *Ichthyomyzon*. M.Sc. thesis, University of Ottawa, 150 pages.

Leach, W. J. 1940. Occurrence and life history of the Northern Brook Lamprey, *Ichthyomyzon fossor*, in Indiana. Copeia 1940(1): 21–34.

McPhail, J. D., and **C. C. Lindsey.** 1970. Freshwater fishes of northwestern Canada and Alaska. Fisheries Research Board of Canada Bulletin 173.

Mongeau, J.-R., P. Dumont, L. Cloutier, et **A.-M. Clément**. 1988. Le statut du suceur cuivré, *Moxostoma carinatum*, au Canada. Canadian Field-Naturalist 102(1): 132–139.

Moore, J. W., and **J. M. Mallatt.** 1980. Feeding of larval lamprey. Canadian Journal of Fisheries and Aquatic Sciences 37(11): 1658–1664.

Morman, R. H., D. W. Cuddy, and **P. C. Rugen.** 1980. Factors influencing the distribution of sea lamprey (*Petromyzon marinus*) in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 37(11): 1811–1826.

Morman, R. H. 1979. Distribution and ecology of lampreys in the lower peninsula of Michigan, 1957-1975. Great Lakes Fisheries Commission Technical Reports 33.

Perlmutter, A. 1951. An aquarium experiment on the American eel as a predator on larval lampreys. Copeia 1951(2): 173–174.

Piavis, W. G. 1971. Embryology. Pages 361–400 *in* The biology of lampreys. *Edited by* M. W. Hardisty and I. C. Potter. Academic Press, London.

Pflieger, W. L. 1971. A distributional study of Missouri fishes. Publications of the Museum of Natural History, University of Kansas 20(3): 225–570.

Purvis, H. A. 1970. Growth, age at metamorphosis, and sex ratio of Northern Brook Lamprey in a tributary of southern Lake Superior. Copeia 1970(2): 326–332.

Reighard, J., and **H. Cummins.** 1916. Description of a new species of lamprey of the genus *Ichthyomyzon*. Occasional Papers of the Museum of Zoology, University of Michigan 31: 1–12.

Sawyer, H. W. 1959. Burrowing activities of the larval lampreys. Copeia 1959(3): 256–257.

Scott, W. B., and **E. J. Crossman.** 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Schuldt, R. J., and **R. Goold.** 1980. Changes in the distribution of native lampreys in Lake Superior tributaries in response to sea lamprey (*Petromyzon marinus*) control, 1953–77. Canadian Journal of Fisheries and Aquatic Sciences 37(11): 1872–1885.

Smith, B. R., and **J. J. Tibbles**. 1980. Sea lamprey (*Petromyzon marinus*) in Lakes Huron, Michigan and Superior: history of invasion and control, 1936–78. Canadian Journal of Fisheries and Aquatic Sciences 37(11): 1780–1801.

Smith, A. J., J. H. Howell, and **G. W. Piavis.** 1968. Comparative embryology of five species of lam-

preys of the Upper Great Lakes. Copeia 1968(3): 461–469.

Starrett, W. C., W. J. Harth, and **P. W. Smith**. 1960. Parasitic lampreys of the genus *Ichthyomyzon* in the rivers of Illinois. Copeia 1960(4): 337–346.

Vladykov, V. D. 1949. Quebec lampreys. List of species and their economical importance. Quebec Department of Fisheries 26: 1–67.

Vladykov, V. D. 1951. Fecundity of Quebec lampreys. Canadian Fish Culturist 10: 1–14.

Vladykov, V. D. 1952. Distribution des lamproies (*Petromyzonidae*) dans la province de Québec. Naturaliste canadien 79: 85–120.

Vladykov, V. D. 1973. North American non-parasitic lampreys of the family Petromyzontidae must be protected. Canadian Field-Naturalist 87: 235-239.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and **J. E. Deacon.** 1989. Fishes of North America endangered, threatened or of special concern: 1989. Bulletin of the American Fisheries Society 14(6): 2–20.

Accepted 31 May 1991

Status of the Chestnut Lamprey, *Ichthyomyzon castaneus*, in Canada*

J. LANTEIGNE

58-2069 Jasmine Crescent, Gloucester, Ontario K1J 7W2

Lanteigne, J. 1992. Status of the Chestnut Lamprey, *Ichthyomyzon castaneus*, in Canada. Canadian Field-Naturalist 106(2): 14–18.

The Chestnut Lamprey, *Ichthyomyzon castaneus*, is rare in Canada judging by the low number of collection records. It is found in the Qu'Appelle River Basin of Saskatchewan and the Red River Basin of Manitoba. These represent the northern limits of the range of this species in North America. It has never been the object of a directed survey in Canada; its precise status is thus unknown. The Chestnut Lamprey is not specifically protected in Canada except for the general protection granted through the fish habitat protection and pollution prevention sections of the Fisheries Act. The paucity of Canadian records supports a status of vulnerable for this species.

La lamproie brune, *Ichthyomyzon castaneus*, est rare au Canada si l'on en juge par le faible nombre d'individus capturés. Elle est présente dans le bassin de la rivière Qu'Appelle, en Saskatchewan, et dans le bassin de la rivière Rouge, au Manitoba. Ces coordonnées représentent les limites septentrionales de l'aire de répatition de l'espèce en Amérique du Nord. Comme elle n'a jamais fait l'objet d'un relevé au Canada, sa situation précise y est inconnue. Elle n'est pas protégée dans les eaux canadiennes, sauf pour la protection générale que lui confèrent les articles sur la protection de l'habitat des poissons et de la prévention de la pollution de la Loi sur les pêches. Sa rare capture dans les eaux canadiennes indique que l'espèce est vulnérable.

Key Words: Petromyzontidae, lampreys, Chestnut Lamprey, lamproie brune, *Ichthyomyzon castaneus*, vulnerable fishes.

The Chestnut Lamprey, *Ichthyomyzon castaneus*, is a parasitic lamprey endemic to North America where it is restricted to tributaries of the Gulf of Mexico, the Gulf of St. Lawrence and Hudson Bay (Lanteigne 1981). The six species which comprise the genus, probably the most primitive among the Northern Hemisphere lampreys (Hubbs and Trautman 1937), can be grouped into three species pairs each composed of a parasitic stem species and a non-parasitic satellite species. After metamorphosis, the parasitic species feed mainly on teleost fishes for one or more years (Scott and Crossman 1973) while the non-parasitic species spawn soon after transformation. All lampreys die soon after spawning, be they parasitic or not.

Description

The adult Chestnut Lamprey can reach a total length of 325 mm (ROM 28500); Hubbs and Trautman (1937) indicate a range of 105 to 310 mm (average 216 mm) while Lanteigne (1981) found a range of 89 to 261 mm. The number of trunk myomeres usually varies from 51 to 54 but can range from 49 to 56 (Hubbs and Trautman 1937). The disc is armed with strong, slender, sharp curved teeth of which the bicuspid endolaterals [usually 5 to 8, most frequently 5 (Lanteigne 1981)] represent the diagnostic character of the species (Figure 1). Its body is dark grey to olive (Cross 1967) and becomes blue-black after spawning, prior to death (Hubbs and Trautman 1937). The lateral line organs are darkly pigmented, especially the ventral ones which become intensely black with maturity (Hubbs and Trautman 1937).

Distribution

In the drainage basins of the Eastern United States (Figure 2) the Chestnut Lamprey is found in the Hudson Bay drainage of North Dakota and Minnesota; in the Western Great Lakes basin, only in tributaries of Lake Michigan and Lake Huron of Wisconsin, Michigan and Indiana; in the Upper Missouri, in Nebraska and Kansas; in the Lower Missouri, in Missouri; in the Upper Mississippi, in Wisconsin, Iowa, Illinois and Missouri; in the Lower Mississippi, in Illinois, Missouri and Mississippi; in the Eastern Gulf, in Mississippi and Alabama; in the Western Gulf, in Texas; in the Lower Arkansas-Red-White, in Kansas, Missouri, Oklahoma, Texas, Arkansas and Louisiana; in the Tennessee-Cumberland, in Kentucky, Tennessee and Alabama; and in the Ohio, in Illinois and Indiana (Lanteigne 1981) [Figure 3].

In Canada, the Chestnut Lamprey is present in the Hudson Bay drainage of Saskatchewan and Manitoba (Figure 4). In the Qu'Appelle River basin

*Report accepted by COSEWIC and Vulnerable Status assigned 9 April 1991.

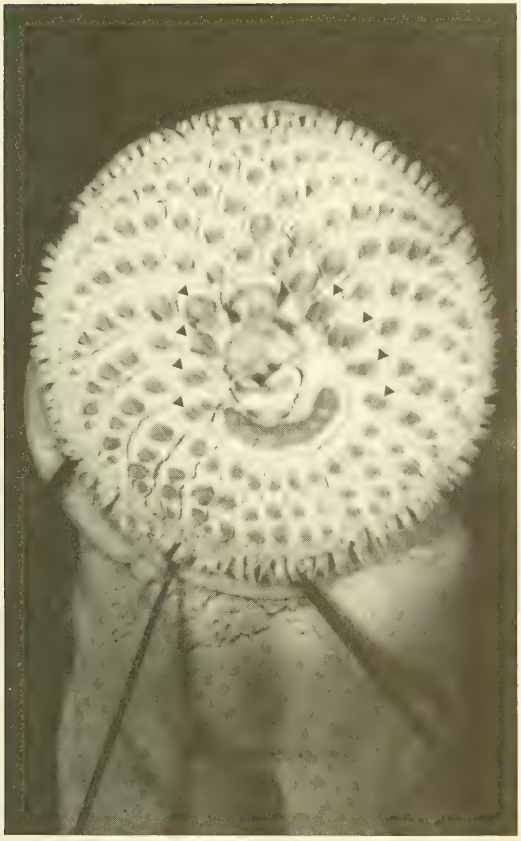


FIGURE 1. *Ichthymomyzon castaneus*: female, 224 mm TL; Black Lake, Ottawa, Co., Michigan, 1 March 1929; J. Metzelaar; UMMZ 101722. Note characteristic bicuspid endolateral teeth, in this case numbering 8.

of Saskatchewan, it has been captured in the Whitesand River (51°34'N, 101°56'W), in Round Lake (50°32'N, 101°22'W), in the Qu'Appelle River at Tantallon (50°32'N, 101°50W) [Royal Ontario Museum (ROM 34319)], and in the Shell River near Shellmouth (50°56'N, 101°29'W), Manitoba (Atton and Merkowsky 1983). In the Red River basin of Manitoba, it has been reported in the Rat River, 9.6 km upstream from St. Malo (49°16'N, 96°51W) [Case 1970], in the Red River (Keleher 1952), between Selkirk and St. Andrews locks (50°09'N, 96°52'W) and at Winnipeg (49°53'N, 97°09'W [ROM 19839]; in Lake Winnipeg, near Black Island (51°12'N, 96°36'W) [ROM 16295] and Dog Head Point (51°45'N, 96°48'W) [ROM 285]; in the Assiniboine River (49°53'N, 97°08'W) [ROM 14341] where it was first reported in Canada at Portage la Prairie (49°59'N, 98°18'W) [Scott and Crossman 1973]; in the Winnipeg River (50°38'N, 96°19'W) [Hinks 1943]; and in Devil Creek at Red River (50°19'N, 96°49'W) [Manitoba Museum of Man and Nature (MMMN 1.5-356)]. This distribution represents the northern limits of the range of this species in North America.

Protection

The Chestnut Lamprey is not listed as endangered, threatened or of special concern in North America (Williams et al. 1989). In Canada, the species is not the object of any legal protection other than the general protection granted under sections 34 to 42 of the Fisheries Act, which pertain to the protection of, and prevention of pollution in, fish habitats. In Manitoba, protection can be offered through the provincial Endangered Species Act by regulation.

Population Sizes and Trends

The Chestnut Lamprey was first reported in Canada by E. S. Thompson in 1898: he recorded the species as present in the Assiniboine River, at Portage la Prairie (49°59'N, 98°18'W) [Scott and Crossman 1973]. Subsequent collections in the Assiniboine River were not made until 1933 (ROM 14341). Since then, its capture in Canadian waters has been incidental but then the species has never been the object of a directed survey as it has no commercial significance. But, like other species, it has been taken in the course of museum and fisheries

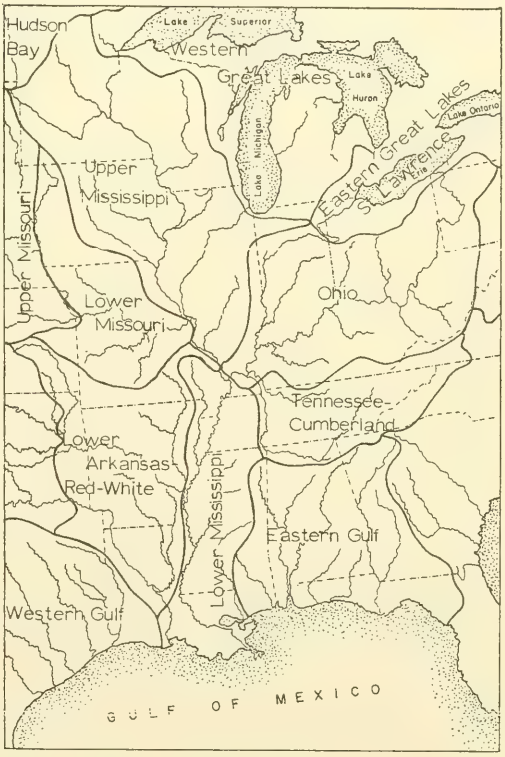


FIGURE 2. Principal drainage basins of Eastern United States where the genus *Ichthyomyzon* is found.

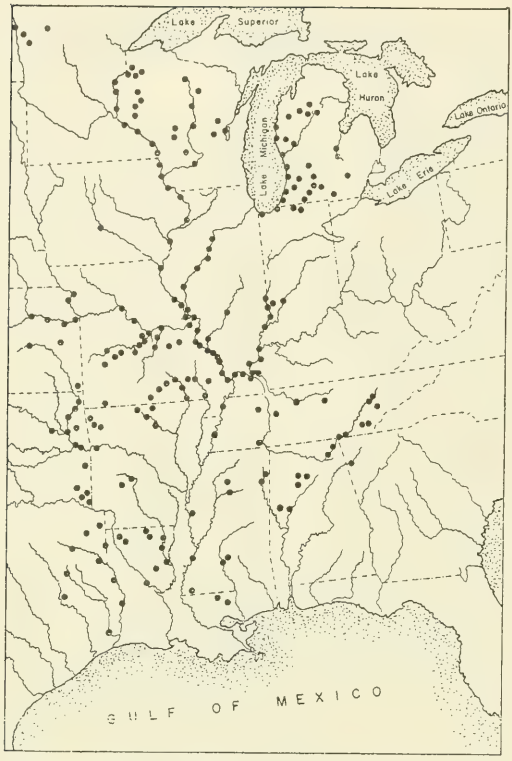


FIGURE 3. Distributional records of *Ichthyomyzon castaneus* in Eastern United States.

surveys. It has never been captured in great numbers. However, Case (1970) observed a spawning group of about 50 spawning adults in the Rat River, which flows into the Red River in Manitoba.

No population estimates are available. There is no indication that the species is in danger of extinction but the state of our knowledge is such that no predictions can be made. The better fish sampling methods used in the last two or three decades may be in part responsible for the greater number of lampreys appearing in fish collections. This increase should therefore not be viewed as a real increase in abundance. On the other hand, tillage of the soil in Western Canada and reduction of native year-round prairie grass and aspenland ground cover has lead to the loss of 37 to 48% of the soil organic content and greatly increased soil erosion (Bird and Rapport 1986) This can be expected to have destroyed some gravel spawning ground and increased mortality of some species through siltation. Periphyton growth may also impact spawning beds through eutrophication from runoff of farm fertilizers. Increased use of pesticides and herbicides in grain farming may have had a negative direct impact on these lampreys or reduced populations of some of their prey species.

Habitat

Adult Chestnut Lampreys appear to inhabit the main course of moderate-sized rivers (Scott and Crossman 1973) and large creeks (Hubbs and Trautman 1937). It spawns in rivers from early to mid-June but possibly as late as early July; the peak of activity is in mid-June (Hubbs and Trautman 1937). In the Rat River, Manitoba, it spawned in areas of coarse gravel at a depth of 38 cm, a water temperature of 16.5°C and a current velocity of about 1 m/sec (Case 1970). The ammocoetes prefer areas of moderate current (about 0.3 to 0.7 m/sec), stable bottom of sand and silt with light growth of *Chara*. Larger ammocoetes found in quiet backwater areas of black muck and silt were only in areas where rooted vegetation was dense (Hall 1960).

General Biology

Reproductive Capability

Like all lampreys, the Chestnut Lamprey breeds only once. The species is between 7 and 9 years old when it spawns, since it is presumed that the ammocoete period lasts from 5 to 7 years. Metamorphosis of ammocoetes begins in August and is completed the following January. Active parasitic feeding begins that spring, with the greatest feeding activity in July. The adults are inactive over the next winter when their gonads start to mature (Scott and Crossman 1973). They mate, spawn and die soon after egg-laying is completed in June or July. The peak of sexual activity is in mid-June when water temperature varies from 16° to 22°C (Morman 1979). *Ichthyomyzon castaneus* seems to be a communal spawner; Case (1970) observed about 50 individuals occupying a single nest in the Rat River, a tributary of the Red River in Manitoba. Spawners were observed excavating areas of coarse gravel riverbed at a water depth of about 38 cm where the river was 9.5 m across. The male would attach to the head of the female and coil its tail around the anterior part of her body. Up to five lampreys were observed attached to each other. Hall (1963) also reported spawning Chestnut Lampreys in a nest well hidden beneath a log. A 284 mm female Chestnut Lamprey captured in Oklahoma contained 42 000 eggs (Hall and Moore 1954). They are elliptical (0.64 mm by 0.56 mm), demersal and non-adhesive (Fuiman 1982). Under experimental conditions, the incubation period lasted 9 days at 18°C (Smith et al. 1968). In the Rat River, many small fishes, chiefly the Common Shiner (*Notropis cornutus*), were present immediately downstream of the nest, probably feeding on the eggs.

Behavior/Adaptability

The young larvae settle down into the soft bottom of slowly flowing waters where they are carried by the current. According to Sawyer (1959), the mouth is directed towards the current, with the upper sec-

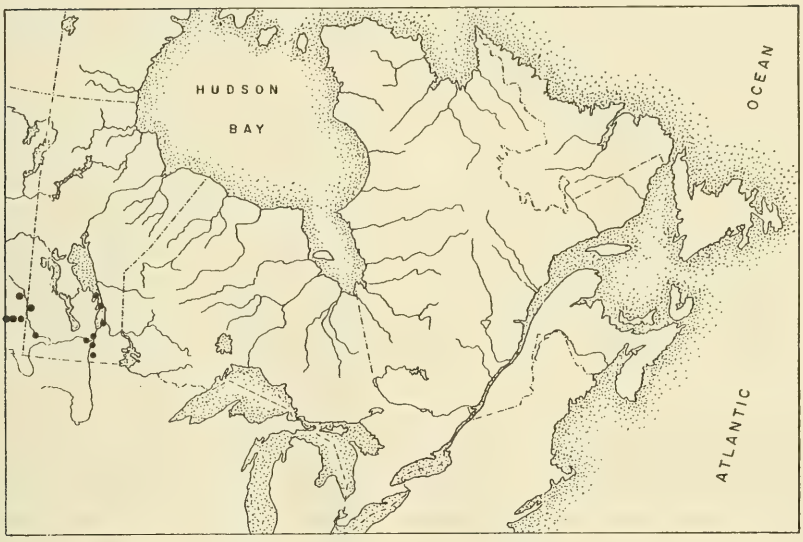


FIGURE 4. Distributional records of *Ichthyomyzon castaneus* in Canada.

tion of the burrow sloping obliquely towards the mud surface. For several years, they lie concealed in the silt deposits, feeding on desmids, diatoms and protozoans (Scott and Crossman 1973) strained from the water. Since their burrows at the substrate surface are sometimes closed off, food may be drawn from the sediments, depending on environmental conditions and activity of the ammocoetes (Moore and Mallatt 1980). In fact, detritus is frequently reported in the gut contents of all species of lampreys, although its relative abundance may vary with season and locality (Hardisty and Potter 1971).

The parasitic adult attacks a wide variety of stream fishes and, like other parasitic lampreys, rasps into the flesh, consuming body fluids and muscles (Scott and Crossman 1973). In Oklahoma, where *castaneus* is the only parasitic lamprey species, Hall and Moore (1954) have found attached lampreys or their scars on the following host species: Shorthead Redhorse (*Moxostoma macrolepidotum*), Golden Redhorse (*Moxostoma erythrurum*), River Redhorse (*Moxostoma carinatum*), Smallmouth Buffalo (*Ictiobus bubalus*), Common Carp (*Cyprinus carpio*), Green Sunfish (*Lepomis cyanellus*), Largemouth Bass (*Micropterus salmonoides*) and Smallmouth Bass (*Micropterus dolomieui*). Hall (1960) observed Chestnut Lampreys attached to a number of stream fishes, including Brook Trout (*Salvelinus fontinalis*), Brown Trout (*Salmo trutta*), Rainbow Trout (*Oncorhynchus mykiss*), White Sucker (*Catostomus commersoni*) and Burbot (*Lota lota*).

Species Movement

No data are available on the migrations of the Chestnut Lamprey. All observers of lamprey migrations nevertheless agree that lampreys are only active during the hours of darkness and that in the daytime they avoid the light, seeking out resting places under rocks or the cover of river banks (Hardisty and Potter 1971). Parasitic lamprey species migrate upstream from feeding areas in lakes and major rivers to spawn in tributaries close to areas where the larvae spend their hidden life (Larsen 1980).

Limiting Factors

The limiting factors are unknown in general, but suitable lamprey spawning and larval habitats seem to be disappearing because of siltation and pollution (Bailey 1959; Starrett et al. 1960). General deterioration in river habitat may reduce available food supply of larvae and adults. Increasing levels of toxic chemicals may cause direct mortality. River eutrophication may subject larvae to low winter oxygen levels and increase mortality due to lack of oxygen or increase predation if they leave their burrow (D.E. McAllister, Canadian Museum of Nature; personal communication).

Special Significance of the Species

All species, lampreys included, are part of our biodiversity heritage. Parasitic species, like the parasitic adult Chestnut Lamprey, play a role in moderating populations of their prey. The larvae function as filter feeders and detritivores and so play a role in recycling dead organic matter into living tissue (Vladykov 1973). While some may feel that all parasitic lampreys should be eradicated, it must be remembered that lampreys are one of the oldest and most successful groups of living fishes (Beamish

1987). As such, they offer an excellent opportunity to study evolution in fishes and the reasons for their continued success in a changing environment. Even though the Chestnut Lamprey has scientific interest, it is doubtful that the general public would support its protection.

Evaluation

Due to its restricted distribution in Canada, the Chestnut Lamprey can be considered a vulnerable species according to COSEWIC definitions. It is not known to be abundant where it occurs in Canada and therefore its parasitism of economically important species is probably negligible in Canadian waters.

Acknowledgments

Financial support for this report was provided through World Wildlife Fund Canada and the Department of Fisheries and Oceans Canada. Thanks are extended to the Royal Ontario Museum and the Canadian Museum of Nature for the provision of collection records. I wish also to acknowledge D. E. McAllister and C. B. Renaud, of the Canadian Museum of Nature, and Karen Lloyd, of the Canadian Wildlife Service, for their helpful comments and review of the manuscript.

Literature Cited

Atton, F. M., and **J. J. Merkowsky.** 1983. Atlas of Saskatchewan fish. Saskatchewan Department of Parks and Natural Resources Technical Reports 83–2.

Bailey, R. M. 1959. Parasitic lampreys (*Ichthyomyzon*) from the Missouri River, Missouri and South Dakota. Copeia 1959(2): 162–163.

Beamish, R. J. 1987. Status of the Lake Lamprey, *Lampetra macrostoma*, in Canada. Canadian Field-Naturalist 101(2): 186–189.

Bird, D. M., and **D. G. Rapport.** 1986. State of the Environment Report for Canada. Environment Canada, Ottawa, Ontario.

Case, B. 1970. Spawning behavior of the Chestnut Lamprey, *Ichthyomyzon castaneus*. Journal of the Fisheries Research Board of Canada 27(10): 1872–1874.

Cross, F. B. 1967. Handbook of fishes of Kansas. University of Kansas Museum of Natural History Miscellaneous Publications 45.

Fuiman, L. E. 1982. Family Petromyzontidae. Pages 23–37 *in* Identification of larval fishes of the Great Lakes basin with emphasis on the Lake Michigan drainage. *Edited by* N. A. Auer. Great Lakes Fisheries Commission Special Publication 82–3.

Hall, J. D. 1960. Preliminary studies on the biology of native Michigan lampreys. M.Sc. thesis, University of Michigan, Ann Arbor, Michigan. 39 pages.

Hall, J. D. 1963. An ecological study of the chestnut lamprey, *Ichthyomyzon castaneus* Girard, in the Manistee River, Michigan. Ph.D. thesis, University of Michigan, Ann Arbor, Michigan. 101 pages.

Hall, G. E., and **G. A. Moore.** 1954. Oklahoma lampreys: their characterization and distribution. Copeia 1954 (2): 127–135.

Hardisty, M. W., and **I. C. Potter** 1971. The behaviour, ecology and growth of larval lampreys and The general biology of adult lampreys. Pages 127–236 *in* The Biology of Lampreys. Volume 1. Academic Press, London.

Hinks, D. 1943. The fishes of Manitoba. Manitoba Department of Mines and Natural Resources, Winnipeg, Manitoba.

Hubbs, C. L., and **M. B. Trautman.** 1937. A revision of the lamprey genus *Ichthyomyzon*. Miscellaneous Publications of the Museum of Zoology, University of Michigan 35.

Keleher, J. J. 1952. Notes on fishes collected from Lake Winnipeg region. Canadian Field-Naturalist 66(6): 170–173.

Lanteigne, J. 1981. The taxonomy and distribution of the North American lamprey genus *Ichthyomyzon*. M.Sc. thesis, University of Ottawa, Ottawa, Ontario. 150 pages.

Larsen, L. O. 1980. Physiology of adult lampreys, with special regard to natural starvation, reproduction and death after spawning. Canadian Journal of Fisheries and Aquatic Sciences 37(11): 1762–1779.

Moore, J. W., and **J. M. Mallatt.** 1980. Feeding of larval lamprey. Canadian Journal of Fisheries and Aquatic Sciences 37(11): 1658–1664.

Morman, R. H. 1979. Distribution and ecology of lampreys in the lower peninsula of Michigan, 1957-1975. Great Lakes Fisheries Commission Technical Reports 33.

Sawyer, H. W. 1959. Burrowing activities of the larval lampreys. Copeia 1959(3): 256–257.

Scott, W. B., and **E. J. Crossman.** 1973. Freshwater Fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Smith, A. J., J. H. Howell, and **G. W. Piavis.** 1968. Comparative embryology of five species of lampreys of the Upper Great Lakes. Copeia 1968(3): 461–469.

Starrett, W. C., W. J. Harth, and **P. W. Smith.** 1960. Parasitic lampreys of the genus *Ichthyomyzon* in the rivers of Illinois. Copeia 1960(4): 337–346.

Vladykov, V. D. 1973. North American nonparasitic lampreys of the family Petromyzonidae must be protected. Canadian Field-Naturalist 87: 235–239.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and **J. E. Deacon.** 1989. Fishes of North America endangered, threatened, or of special concern. 1989. Fisheries 14(6): 2–20.

Accepted 31 May 1991

Status of the Y-Prickleback, *Allolumpenus hypochromus*, in Canada*

R. E. CAMPBELL

2880 Carling Avenue, #1410, Ottawa, Ontario K2B 7Z1

Campbell, R. E. 1992. Status of the Y-Prickleback, *Allolumpenus hypochromus*, in Canada. Canadian Field-Naturalist 106(1): 19–23.

The Y-Prickleback, *Allolumpenus hypochromus*, is a small stichaeid known only from the southwest coastal waters of British Columbia. Although literature records extend the range to southern California, reports from U.S. waters are not confirmed. Information on its biology and ecology is extremely limited, but it appears to be a rare species with a narrow distribution limited by its habitat requirements. Despite its apparent rarity, viable populations exist and the status of the species appears to be secure for the present.

La lompénie i-grec, *Allolumpenus hypochromus*, est un petit stichéide connu seulement des eaux côtières du sud-ouest de la Colombie-Britannique. Bien que la littérature scientifique rapport sa présence jusqu'au sud de la Californie, les mentions de cette espèce dans les eaux des Etats-unis ne sont pas corroborées. Les données sur la biologie et l'écologie de cette éspèce sont très limitées, mais l'espèce est apparemment rare avec une répartition restreinte limitée par ses besoins d'habitat. Néanmoins, des populations viables existent, et le statut de cette espèce semble être stable à ce moment-ci.

Key Words: Stichaeidae, pricklebacks, Opisthocentrinae, Y-Prickleback, lompénie i-grec, *Allolumpenus hypochromus*, Y-Blenny, marine fishes.

The Y-Prickleback, *Allolumpenus hypochromus* Hubbs and Schultz 1932, is a small marine fish known from a very few specimens recorded off the coast of British Columbia. The species was first described in 1932 (Hubbs and Schultz 1932) but there have been few reported sightings since (see Table 1).

It is difficult enough to ascertain the status of a species confined in lakes or streams, but it is even more difficult to evaluate the status of poorly known species in the immensity of the ocean. If collection records or surveys indicate that a species is rare, is this simply an artifact of sampling methods and effort? Some species believed to be rare have been found to be locally common when directed surveys were undertaken using appropriate gear in the true habitat (McAllister et al. 1985). Current status, however, must be evaluated in terms of known specimens and degree of sampling.

Description

The Stichaeidae are a fairly large family (37 genera, with about 74 species) of circumboreal, bottom dwelling, marine fishes (Hart 1973; Nelson 1984; McAllister 1990). Pricklebacks have elongated, compressed or cylindrical bodies with a long dorsal fin (entirely spinous in most species) extending the length of the body and sometimes confluent with the caudal fin. The anal fin is also long and may be confluent with the caudal fin. The pelvic fins, if present, are reduced, and consist of one spine and three or four rays. The lateral line is usually not well developed (though four lateral lines have been recorded) and the body is covered with small, circular overlapping scales. Eight species occur in the Canadian Atlantic, two in the Arctic, and some 14 in the Canadian Pacific (Hart 1973; Scott and Scott 1988; McAllister 1990).

The Y-Prickleback is a member of the subfamily Opisthocentrinae, characterized by pelvic fins with one spine and three soft rays, large pectoral fins, lateral line canal and pores indistinct or absent, and 53-94 vertebrae (Makushov 1958). This species is the only representative of its genus. It is distinguished by the united gill membranes joined to the isthmus at the centre, the Y-shaped markings (Figure 1), spots at the base of the dorsal fin, the long pelvic fins with one spine and three soft rays, the dorsal fin with 49 spines, and the anal fin with one spine and 31 rays (Hubbs and Schultz 1932; Clemens and Wily 1961; Hart 1973).

The following general description is based on Hubbs and Schultz's (1932) description of the holotype. These are small fish measuring to 7.4 cm standard length. The body is slender, moderately elongate and slightly compressed anteriorly and covered with small cycloid scales except for the head which is naked. The head is bluntly rounded; the mouth terminal and moderate in size, extending to a point below the middle of the large, oval eye. There are

*Report accepted by COSEWIC 9 April 1991, No Status Designation Required.

TABLE 1. Existing specimen records of *Allolumpenus hypochromus*. All are from British Columbian waters.

Source	Location (latitude, longitude)	Date
Hubbs and Schultz (1932)	Newcastle Island, near Naniamo (Holotype) [see also UBC 72-152].	8 August 1927
NMC 65-0043	Browning Entrance, Queen Charlotte Islands (53°40′00″N, 130°34′00″W)	17 June 1964
UBC 65-0295	Baker Passage, Vancouver Island (50°01′00″N, 124°56′00″W)	27 June 1962
UBC 65-096	Malcom Island (50°40′24″N, 127°11′00″W)	12 June 1963
UBC 72-152	Newcastle Island (49°12′00″N, 123°56′00″W)	–
BCPM 984-421	Tasu Sound, Queen Charlotte Islands (52°04′30″N, 132°00′24″W)	16 September 1984

NMC: National Museums of Canada (National Museum of Natural Sciences: renamed Canadian Museum of Nature, 1 July 1990).
UBC: University of British Columbia
BCPM: British Columbia Provincial Museum (now Royal British Columbia Museum).

moderate-sized teeth on both jaws, but the vomerine and palatine bones are toothless. The lateral line canal and pores are absent. The caudal peduncle is compressed and both the anal and dorsal fins are free of the caudal. Makuskov (1958) pointed out that fishes without an obvious lateral line usually lack the canal and/or pores, but have the lateral line neurocysts – the essential lateral line.

The overall colour is brownish with a striking and distinctive irregular series of black markings on the sides of the body. Some of these form a distinct "Y" below the midline (Figure 1). There is also a series of five dark spots along the base of the dorsal fin (located between dorsal spines 11-12, 20-21, 29-30, 38-39, and 44-46), and dorsal and ventral black spots at the base of the caudal fin connected by a black bar (Hubbs and Schultz 1932; Clemens and Wily 1961; Hart 1973).

Distribution

The species has been reported to be endemic to Canada (McAllister et al. 1985) where it is known (from *bon a fide* records) only from Departure Bay, Baker Pass, Saanich Inlet, and Browning Entrance, British Columbia (Figure 2, Table 1). DeLacy et al. (1966) listed the species in their unpublished list of fishes of Puget Sound, but omitted it in an earlier unpublished checklist (DeLacy et al. 1963). It is not included in their subsequent published report (DeLacy et al. 1972). There is apparently no data to substantiate the earlier inclusion (A. E. Peden, British Columbia Provincial Museum, Victoria, British Columbia; personal communication).

Eschmeyer and Herald's (1983) distribution for the species from southern British Columbia to California may be in error as its presence in waters off California has not been confirmed (R. N. Lea, California Department of Fish and Game, California Fisheries Laboratory, Golden Beach, California; personal communication). The Eschmeyer and Herald (1983) citation may have been based on Hubbs et al. (1979), which also lacked reference to collection data, or be based on the unpublished work of DeLacy et al. (1966). None are recorded at the University of Washington (T. Pietsch, University of Washington, Seattle, Washington; personal communication).

There is no known reason for the species to be limited to Canadian waters; similar habitats may exist along the U.S. coast from Washington to northern California (W. N. Eschmeyer, California Academy of Sciences, San Francisco, California; R. N. Lea; personal communications). The species is poorly known because of its small size (it would not be caught, for example, in commercial fish or shrimp gear) and its existence in a habitat which does not make for easy collecting (Peden, personal communication).

Protection

There is no specific legislation for the protection of the species. General protection , if required, could be provided under appropriate sections of the Fisheries Act.

Population Sizes and Trends

Detailed information on population sizes and trends for this species is lacking. It is documented only in Canada, and only from presence/absence data.

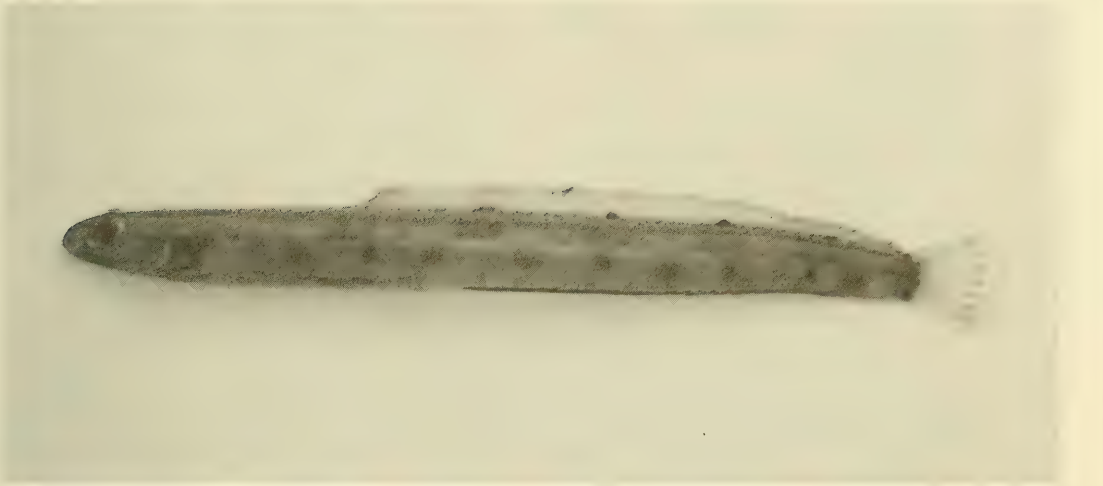


FIGURE 1. Photograph of a freshly caught specimen (53 mm) of the Y-Prickleback, *Allolumpenus hypochromus*, (BCPM 984-421) taken in Tasu Sound, Fairfax Inlet, Queen Charlotte Islands 16 September 1984. Photograph courtesy A. E. Peden, British Columbia Provincial Museum. (Note anterior spines of the dorsal fin are depressed and should be raised like the rest of the fin).

McAllister et al. (1985) suggested that the species should be considered rare (vulnerable) in Canada and protected as such. However, Peden (personal communication) feels that the species is poorly known because of its small size and its habitat. Lea and Eshmeyer (personal communications) are of a similar opinion and suspect that the species range does extend south to California, but has simply gone unnoticed. This may be, but given the distinctive markings of this species it is doubtful it would be missed, if present, in collections, or misidentified with other members of the family. General collection survey activity has been fairly vigorous along the Pacific coast (e.g., Peden and Gruchy 1971; Barraclough and Peden 1976), with several new species and range expansions of others being documented.

In addition to the few *bon a fide* Canadian records (Table 1), Peden (personal communication) observed several individuals on a trip to the Queen Charlotte Islands with the submersible "Pisces IV". Barraclough and Fulton (1968) also reported the presence of larval *Allolumpenus hypochromus* individuals in surface trawl tows in Saanich Inlet during June and July 1966, indicating the presence of a viable population in the area.

Habitat

The recorded specimens (Table 1) were captured at depths varying from about 30 to 100 m over rocky or sandy substrates. Peden (personal communication) observed several specimens from the "Pisces IV" on a very steep slope of detritus and broken shell on the side of a rock wall. The Canadian Museum of Nature specimen came from a similar sand, coral and fine shell bottom. The location was sheltered from tide and wave flow. Barraclough and Fulton (1968) collected 13 mm larvae on the surface of Saanich Inlet, mid-channel, in June and July.

No other information concerning the habitat of the species is apparently available, but most species of this group prefer cool waters (close to 0°C) and high salinity (above 30%) and are benthophages (Andriashev 1954; Makushov 1958).

General Biology

The biology of the species has not been studied and very little is known concerning the biology of the other species and genera in the subfamily. No reproductive or growth data are available. Recorded fecundities for some members of the subfamily are low, usually less than 1000 eggs (Andriashev 1954).

Generally, the smaller stichaeids are said to be benthophagic, feeding on small polychaetes, molluscs and crustaceans (Andriashev 1954). Barraclough, and Fulton (1968) recorded that the larvae they collected appeared to have been feeding on copepods. This species has not been reported from the stomach contents of other fishes. Other members of the group have been reported as prey for larger fishes (Andriashev 1954; Scott and Scott 1988).

Limiting Factors

Not known! If the habitat is limited by water temperature as for most species in the family (Andriashev 1954), they may not be found much further south than has been documented.

FIGURE 2. Map of the world distribution of the Y-Prickleback, *Allolumpenus hypochromus*. The five locations shown are documented in Table 1.

Special Significance of the Species

The Y-Prickleback is of no commercial interest and probably is not an important forage species. The lack of information and its peculiar markings lend an air of mystery to the species. It should be of scientific relevance in determining the evolution of coastal and offshore marine habitats.

Evaluation

Based on *bon a fide* records it appears that the species is endemic to Canada and is a relatively rare member of the British Columbia coastal marine fauna. There are at present no known threats to the species or its habitat and, despite the perceived rarity, viable populations appear to exist. The future of the species would seem to be secure for the present. However, all known specimens come from a very limited area where they are vulnerable to a single destructive event of only modest scale (e.g. ocean dumping of toxic materials).

Literature Cited

Andriashev, A. P. 1954. Ryby sevemykh morei SSSR. Akademiya Nauk Soyuza Sovetskikh sotsialisticheskikh Respublik, Moskoa – Leningrad: 244–275. [Fishes of the northern sea of the U.S.S.R. Translated from Russian. Israel Program for Scientific Translations, Jerusalem 1964.

Barraclough, W. E., and **J. D. Fulton.** 1968. Data record food of larval and juvenile fish caught with a surface trawl in Saanich Inlet during June and July 1966. Fisheries Research Board of Canada Manuscript Report Series Number 1003: 1–78.

Barraclough, W. E., and **A. E. Peden.** 1976. First records of the pricklebreast poacher (*Stellerina xyosterna*), and the cutfin poacher (*Xeneretmus leiops*) from British Columbia, with keys to the poachers (Agonidae) of the Province. Syesis 9: 19–23.

Clemens, W. A., and **G. V. Wilby.** 1961. Fishes of the Pacific coast of Canada. Fisheries Research Board of Canada Bulletin 68: 1–443.

DeLacy A. C., R. L. Dryfoos, and **B. S. Miller.** 1963. Preliminary checklist of the fishes of Puget Sound. [Unpublished Report]. Division of Marine Resources, University of Washington, Seattle, Washington.

DeLacy A. C., R. L. Dryfoos, and **B. S. Miller.** 1966. Preliminary checklist of the fishes of Puget Sound corrected to 1966. [Unpublished Report]. Division of Marine Resources, University of Washington, Seattle, Washington.

DeLacy A. C., R. L. Dryfoos, and **B. S. Miller.** 1972. Checklist of Puget Sound fishes. Washington Sea Grant Publications, Division of Marine Fisheries, University of Washington, Seattle, Washington. 43 pages.

Eschmeyer, W. N., and **E. S. Herald.** 1983. A field guide to Pacific coast fishes of North America. Houghton Mifflin, Boston, Massachusetts. 336 pages.

Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin 180: 1–740.

Hubbs, C. L., and **L. P. Schultz.** 1932. A new blenny from British Columbia with records of two other fishes new to the region. Contributions to Canadian Biology and Fisheries 7(22): 319–324.

Hubbs, C. L., W. I. Follett, and **L. J. Dempster.** 1979. List of the fishes of California. Occasional Papers of the California Academy of Sciences Number 133: 1–51.

Lindberg, G. U., and **Z. V. Krasyukova.** 1975. [Fishes of the Sea of Japan and adjoining parts of the Okhotsk and Yellow Seas]. In Russian. Nauka Press, Leningrad, Part 4: 27–109.

Makuskov, V. M. 1958. The morphology and classification of the northern Blennioid fishes (Stichaeoidae, Blennioidei, Pisces). Proceedings of the Zoological Institute (Trudy Zoological Institute – Akademiya Nauk Soyuza Sovetskikh Satsialisticheskikh Respublik) 25: 3–129. [Translated from the Russian by the Ichthyological Library, U.S. National Museum 1959].

McAllister, D. E. 1990. List of the fishes of Canada. Syllogeus (64): 1–310.

McAllister, D. E., B. J. Parker, and **P. M. McKee.** 1985. Rare, endangered and extinct fishes in Canada. Syllogeus 54: 1–193.

Nelson, J. S. 1984. Fishes of the world. Second edition. John Wiley & Sons, Toronto, Ontario. 523 pages.

Peden, A. E., and **C. G. Gruchy.** 1971. First record of the blue-spotted poacher, *Xeneretmus truacanthus*, in British Columbia. Journal of the Fisheries Research Board of Canada 28: 1347–1348.

Scott, W. B., and **M. G. Scott.** 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences Number 219. 731 pages.

Accepted 31 May 1991.

Status of the Pixie Poacher, *Occella impi*, in Canada*

R. E. Campbell

2880 Carling Avenue #1410, Ottawa, Ontario K2B 7Z1

Campbell, R. E. 1992. Status of the Pixie Poacher, *Occella impi*, in Canada. Canadian Field-Naturalist 106(1): 24–26.

The Pixie Poacher, *Occella impi*, was first recognized as a distinct species endemic to the Canada fauna little more than 20 years ago. The species was described from a single juvenile specimen collected in 1957 from the Queen Charlotte Islands of British Columbia. There is no other information regarding the species beyond that published with the description. This apparently rare species appears to be restricted to a habitat vulnerable to catastrophic events.

Il y a un peu pleu de vingt ans, en reconnaissait le lutin, *Occella impi*, comme une espèce endémique à la faune canadienne. L'espèsce put décrite à partir d'un seul spécimen juvénile collectionné en 1957 près des Iles de la Reine Charlotte en Colombie-Britannique. De fait, il n'y en a pas d'autre information concernant cette espèce sauf ce qui a été publiée avec la description. La répartition de cette espèce, manifeste comme rare, semble être limitée à un habitat vulnérable à des événements catastrophiques.

Key Words: Poachers, Agonidae, Pixie Poacher, lutin, *Occella impi*, marine fishes, North Pacific, British Columbia.

Sea poachers (Agonidae) are members of a family of small, marine, bottom dwellers distinguished by the body covering of non-overlapping rows of adjoining bony plates in place of scales. These are fishes primarily of the North Pacific Ocean, although three species are known from the North Atlantic (Scott and Scott 1988), and another from the South Pacific (J. S. Nelson, Department of Zoology, University of Alberta, Edmonton, Alberta; personal communication).

The Pixie Poacher, *Occella impi* Gruchy 1970, was described from a single specimen from Graham Island, Queen Charlotte Islands, British Columbia in 1957. The species has not been reported since. Due to its apparent rarity, and occurrence in a habitat now susceptible to potentially catastrophic events such as oil spills, the status of this endemic species is of concern to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Description

The Pixie Poacher is a small fish, the single individual described by Gruchy (1970) [Canadian Museum of Nature catalogue number 60-283] was presumed to be a juvenile and is 20.6 mm total length [TL] (Figure 1). Gruchy (1970) recognized the species as a poacher (Brachyospininae) rather than an alligatorfish. The Pixie Poacher is elongate with a long caudal peduncle and in place of scales the body is covered by rows of adjoining ridged or spinous plates. There is a small, flaplike barbel at the posterior end of the upper jaw (Gruchy 1970; Hart 1973). The species has two dorsal fins, a rounded caudal fin and long pectoral fins which stretch beyond the origin of the first dorsal fin. The pelvic fins are small and inserted well forward on the thorax (Gruchy 1970).

The preserved specimen is brown in colour, the ventral surface being slightly lighter. The body lacks distinctive markings although the peduncle appears more heavily pigmented as does the base of the caudal fin. A brownish stripe is apparent on the upper third of the base of the pectoral fin (Gruchy 1970; Hart 1973).

Identifying features (relative to other agonids) include the deep head, pits along the lower jaw and suborbital ridge, the posterior position of the anus, pricklelike plates on the breast and the scarcity of dorsolateral plates (Hart 1973). Gruchy (1970) also mentions the presence of vomerine and palatine teeth as diagnostic.

Distribution

Known only from the single record from Graham Island (Figure 2), Queen Charlotte Islands, British Columbia (54°02'N, 132°00'W).

Protection

No specific legislation exists for the protection of the species. General protection is available, if required, through the Fisheries Act.

Population Sizes and Trends

No information on possible population sizes and trends is available. Hart (1973) speculated that, given the small size of the fish and its tidal pool habitat, it may be quite common. However, the specimen described (Gruchy 1970) was thought to be a

*Report accepted by COSEWIC 9 April 1991, Insufficient scientific information for status determination.

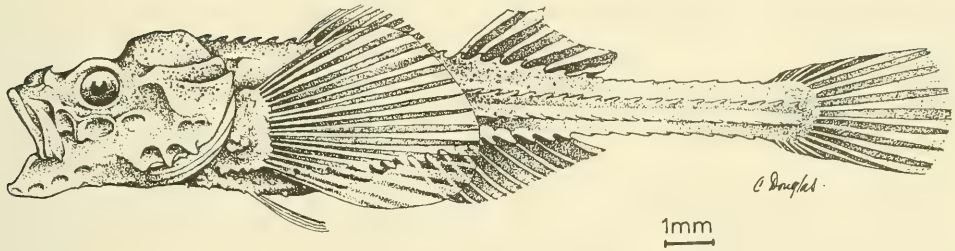


FIGURE 1. Holotype of *Occella impi* (NMC60-283) [drawing by C. Douglas, courtesy of D. E. McAllister, Canadian Museum of Nature].

juvenile and the adults, if like other agonids (Andriashev 1954) would probably not be found in this habitat except during spawning. In addition, the species has not been reported in subsequent collections since the record of the first specimen in 1957 despite repeated sampling for agonids in the area (Peden and Gruchy 1971; Miller and Lea 1972; Hart 1973; Barraclough and Peden 1976). This lack of further collections is particularly surprising as these surveys have confirmed the presence of other agonids known from the area. In addition, they have added new records for the Cutfin Poacher (*Xeneretmus leiops*) and the Pricklebreast Poacher (*Stellerina xyosterna*), previously known only from United States coastal waters to the south (Barraclough and Peden 1976). The previously known range of these species was extended by 280 and 850 km respectively.

Habitat

Habitat preferences of the Pixie Poacher are not known. The holotype was collected from a brackish tidal pool, between high and low tides, on a coarse sand pebble beach at the mouth of the Skonum River, McIntyre Bay, Graham Island, British Columbia (Bousfield 1962).

Adults of closely related species are most often encountered in coastal waters at depths of 18 to 90 m on sandy and muddy bottoms (Andriashev 1954; Hart 1973; Barraclough and Peden 1976), while juveniles and larvae are found in shallower inshore sandy habitats (Barraclough and Peden 1976).

Shrimp, juvenile crabs, sand dollars, small sole, and sculpins are often found in association with juvenile agonids in inshore collections (Barraclough and Peden 1976).

Biology

Not known. The poachers are, in general, a poorly studied group of fishes. Adults are thought to enter shallow bays and deltas to spawn in the spring (Andriashev 1954). The eggs are small, averaging 1.5 mm in diameter, and females lay less than 1000 eggs, probably 400 to 500 (Andriashev 1954).

The sex and age of the holotype have not been determined, but Gruchy (1970) assumed it to be a juvenile based on the location of capture and the length (20.6 mm TL). Juveniles of closely related species such as the Pricklebreast and Warty (*Occella verrucosa*) poachers are found in similar habitat and range from 15 to 37 and 28.5 to 42.0 mm TL respectively. Adults of these are considerably larger, up to 97 mm TL (Barraclough and Peden 1976).

Agonids swim using the pectoral fins and are thought to feed on copepods, euphasiids, and decapods (Andriashev 1954; Hart 1973). Larvae and juveniles are found inshore in sheltered bays and deltas (Andriashev 1954).

Limiting Factors

Not known. A catastrophic event such as a major oil spill has the potential for serious affects on juveniles in inshore habitats.

Special Significance of the Species

With the exception of the Warty Poacher, this is the only species of the genus *Occella* known from Canada. Too small to be of commercial importance, they may serve as a forage fish for larger species. Agonids from the North Atlantic and the Arctic have been reported from the stomachs of cod, haddock and halibut, but bony plates may make them unattractive as prey (Scott and Scott 1988).

Occella impi is of particular interest in that it is known from a only single specimen. The species has been recognized by the American Fisheries Society [AFS] (Robins et al. 1980).

Evaluation

It would be logical to assume that the species should be considered rare and vulnerable. However, the family in general is poorly understood and there is some question as to the validity of the species (A. E. Peden, British Columbia Provincial Museum, Victoria, British Columbia; personal communication). If it is a valid species, it is probably rare in Canadian waters. The species is not under any present threat, but eggs, larvae and juveniles would be susceptible to a major oil spill, such as that which

FIGURE 2. Known distribution of *Occella impi* (single record from Graham Island, 54°02'N, 132°00'W).

recently occurred further north in Alaska. Tanker traffic off the British Columbia coast poses regular risk to all British Columbian shallow water marine fishes.

Literature Cited

Andriashev, A. P. 1954. Fishes of the northern seas of the U.S.S.R. Translated from the Russian. Israel Program for Scientific Translation, Jerusalem 1964. Number 836: 453–471.

Barraclough, W. E., and **Alex E. Peden.** 1976. First records of the pricklebreast poacher (*Stellerina xyosterna*), and the cutfin poacher (*Xeneretmus leiops*) from British Columbia, with keys to the poachers (Agonidae) of the Province. Syesis 9: 19–23.

Bousfield, E. L. 1962. Investigations on seashore invertebrates of the Pacific Coast of Canada 1957 and 1959. I. Station List. National Museums of Canada Bulletin 1985: 72–89.

Gruchy, C. G. 1970. *Occella impi*, a new species of sea poacher from British Columbia with notes on related species (Agonidae: Pisces). Journal of the Fisheries Research Board of Canada 27: 1109–1114.

Hart, J. L. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada Bulletin 180: 1–740.

Miller, D. J., and **R. N. Lea.** 1972. Guide to the coastal marine fishes of California. California Department of Fish and Game, Fisheries Bulletin 157: 1–235.

Peden, A. E., and **C. G. Gruchy.** 1971. First record of the blue spotted poacher, *Xeneretmus truacanthus*, in British Columbia. Journal of the Fisheries Research Board of Canada 28: 1347–1348.

Robins, C. R. [*Chairman*], **R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea,** and **W. B. Scott.** 1980. A list of common and scientific names of fishes from the United States and Canada. American Fisheries Society, Bethesda, Maryland, Special Publication Number 12: 1–174.

Scott, W. B., and **M. G. Scott.** 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences Number 219: 731 pages.

Accepted 31 May 1991

Status of the Mountain Sucker, *Catostomus platyrhynchus*, in Canada*

R. E. Campbell

2880 Carling Avenue #1410, Ottawa, Ontario K2B 7Z1

Campbell, R. E. 1992. Status of the Mountain Sucker, *Catostomus platyrhynchus*, in Canada. Canadian Field-Naturalist 106(1): 27–35.

The Mountain Sucker, *Catostomus platyrhynchus*, is the most widely distributed member of the subgenus *Pantosteus*. It is found in the Columbia, Fraser, Saskatchewan and Missouri river systems of Canada as well as the United States where it also occurs in the Green River system and is present in various systems of the Great Basin. Information on the distribution, abundance and life history of the species is limited, but it appears to be less abundant in the northern parts of the range, particularly British Columbia and Washington. A creature of mountain streams, its distribution and ecology is closely related to the zoogeographic history of the region. The present distribution in relation to historic and present hydrographic features and fossil evidence suggests that populations may still be expanding in concert with tectonic and orographic processes, having survived the latest period of glaciation in Columbia and Missouri refugia. Physical and ecological barriers inherent in mountainous habitats give rise to widely separated, genetically diverse populations, the nature of which has led to speculation on the rarity of the species. Although the full extent of the distribution of Canadian populations may not be known there are several widely scattered and diverse viable populations in the west which do not seem to be currently under any threat.

Le meunier des montagnes, *Catostomus platyrhynchus*, a la plus grande répartition de toutes les espèces du sous-genre *Pantosteus*. On peut la trouver dans les systèmes des rivières Columbia, Fraser, Saskatchewan et Missouri au Canada et aux Etats-Unis où elle habite également le système de la rivière Green et divers systèmes du Great Bassin. On dispose de peu de données sur la répartition, l'abondance, et le cycle vital de l'espèce, mais elle semble moins abondante dans le secteur septentrional de son aire de répartition, surtout en Columbie-Britannique et dans l'État de Washington. Il est un poisson typique des ruisseux de montagnes. La répartition et l'écologie de l'espèce sont étroitement liés à l'histoire zoogéographique de la région. La répartition actuelle relativement aux caractéristiques hydrographiques passées et présentes et aux données obtenues des fossiles porte à croire que les populations slaccroissent de concert avec les processus tectoniques et orographiques. L'espèce a survécu à la dernière période de glaciation dans les refuge des rivières Colombia et Missouri. Les barrières physiques et écologiques naturelles des habitats montagneux produisent des populations isolées et différentes au niveau génétique, et ceci a soulevé des conjectures sur la rareté de l'espèce. Quoique l'aire de réparition définitive des populations canadiennes n'ait pas encore été établie, il existe plusieurs différentes populations viables dispersées dans l'ouest du pays et qui ne semblent pas être présentement menacées.

Key Words: Mountain Sucker, *Catostomus platyrhynchus*, Plains Mountain Sucker, Jordan's Sucker, Meunier des Montagnes, Catostomidae, suckers, rare fishes.

The Mountain Sucker, *Catostomus platyrhynchus* (Cope 1874), also commonly known as the Northern Mountain Sucker or Plains Sucker, was long known as *Pantosteus jordani* Evermann. The mountain suckers in the former genus *Pantosteus* (now considered as a subgenus of *Catostomus*) are small suckers of the mountainous regions of western North America. Eight species had formerly been recognized in the genus *Pantosteus* (Bailey et al. 1960), but Smith (1966) reviewed the taxonomy of the group and reduced its status to that of a subgenus of the genus *Catostomus*. This revision includes five species embracing the previously recognized eight, and an additional species (*Catostomus columbianus*) previously considered unrelated. Although it does not completely resolve the taxonomic issues in relation to generic status between *Pantosteus* and *Catostomus*, it is generally accepted (Scott and Crossman 1973; Robins et al. 1980).

The Mountain Sucker is the most widely distributed member of the subgenus (Hauser 1969). Scott and Crossman (1973: 548) suggest that, "nowhere is it abundant or widely distributed" in Canada. This report examines the status of the species in Canada as requested by the Fish and Marine Mammal Subcommittee of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Description

Mountain Suckers are small catostomids averaging 127 to 152 mm total length [TL] (Sigler and Miller 1963). Smith (1966) indicated maximum size in the order of 175 mm standard length (SL), although Hauser (1969) reported seeing an individu-

*Report accepted by COSEWIC 9 April 1991, no status designation required

al 226 mm TL, and the Royal Ontario Museum (ROM) collection includes a 232 mm male (Figure 1) collected in Alberta in 1964 (ROM 25919). The following account is largely based on descriptive material from Sigler and Miller (1963), Carl et al. (1967), Smith (1966), and Scott and Crossman (1973).

The body is elongate, cylindrical and somewhat compressed caudally. The snout is broad and heavy, the eye small, the mouth large and ventral, the edge of the lower jaw having a sharp-edged cartilaginous sheath and the lower lip has the shape of paired wings (Figure 1). There are definite notches at the corners of the mouth (at the point of lateral connection of the upper and lower lips) and an incomplete medial cleft to the lower lip, which is markedly convex anteriorly, with three to five rows of large, round papillae covering the base. The upper lip is large and the outer surface without papillae; there are no teeth in the mouth and the pharyngeal teeth are flat and comblike. There are generally 23 to 37 gill rakers on the external row of the first arch and 31 to 51 on the internal row. The fontanelle is usually reduced to a narrow slit, but may be obliterated; the peritoneum is black or dusky; the intestine is long with six to 10 coils anterior to the liver; there are no pyloric caeca. A two-chambered swimbladder is present, but is reduced, the slender posterior chamber extending to about the point of origin of the pelvic fins. Post-weberian vertebrae number 38 to 44, usually 40 to 43. Cycloid scales cover the body, usually crowded towards the head; the lateral line is complete and straight, the number of scales varying from 60 to 108 throughout the range (79-89 in British Columbia). There is one dorsal fin with eight to 13 soft rays (over the range, 10 or 11 in B.C.); the caudal fin is not long or deeply forked; the anal has seven rays; the pelvics are located well back in line with the middle of the base of the dorsal fin, usually with nine rays and a well developed axillary process; the pectorals are long with 15 rays.

Dorsally, these fish are dark green to grey or brown in colour, usually finely sprinkled with black and the ventral surface is pale yellow to white. The lateral line is not prominent, but there is usually a dark green to black lateral band and/or five dorsal blotches of fine black pigment. The fins are virtually colourless, although a faint red tinge may be evident. Young fish have three dark vertical bars and a black peritoneum which may be observed in external observation. Snyder (1983) provides a description (and key) of larvae and early juveniles.

Breeding fish develop an orange to deep red lateral band and the fin rays may become more heavily pigmented. Breeding males also develop minute nuptial tubercles on the entire body surface, and larger tubercles may be found on the lower lobe of the caudal fin, the dorsal surface of paired fins and on the anal fin. Nuptial tubercles may also be found on the breeding females but these are generally smaller and less abundant than in the males. Smith (1966), Hauser (1969), and Scott and Crossman (1973) provide more details.

This species can be distinguished from other catostomids, except *Catostomus columbianus*, the Bridgelip Sucker, by the incomplete cleft of the lower lip (Figure 1). The notches at the corners of the mouth, the absence of papillae on the anterior vertical surface of the lips and lower scale and fin ray counts may be used to separate it from *C. columbianus* (Smith 1966; Carl et al. 1967).

Distribution

The range of *Catostomus platyrhynchus* is confined to the fresh waters of mountainous regions in western North America (Figure 2), though they extend to the Cypress Hills in the Canadian prairie. Mountain Suckers occur "in streams of the Great Basin in Utah, Nevada and California; headwaters, North Fork Feather River, California; headwaters of the Green River in Utah, Colorado and Wyoming; parts of the Columbia River drainage in Wyoming, Idaho, Washington, Oregon and British Columbia; Fraser River drainage, British Columbia; upper Saskatchewan River drainage, Saskatchewan and Alberta; Milk River drainage, Montana and

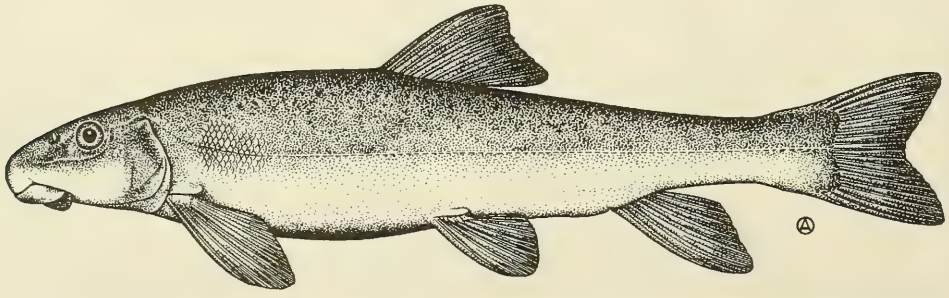


FIGURE 1. Mountain Sucker, *Catostomus platyrhynchus*. Male; 232 mm; ROM 25919; drawing by A. Odum, reproduced from Scott and Crossman (1973) by permission.

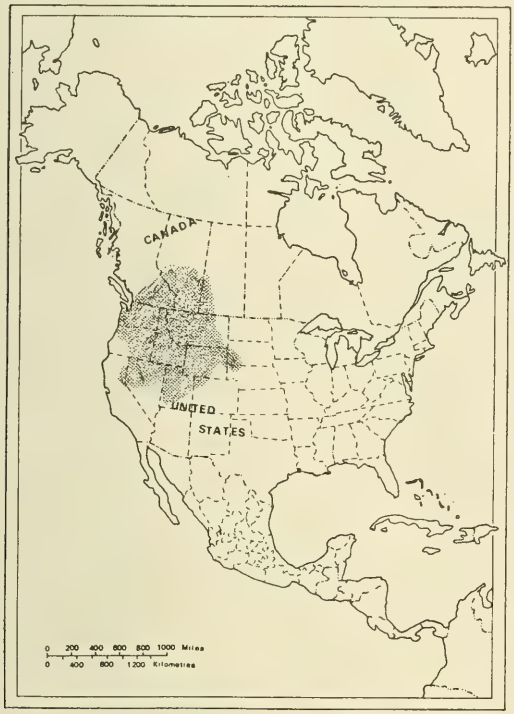


FIGURE 2. Approximate North American range of the Mountain Sucker, *Catostomus platyrhynchus*.

Saskatchewan; upper Missouri River drainage, Montana and Wyoming, and the Black Hills, South Dakota; White River and formerly, possibly, the Niobrara River, Nebraska" (Smith 1966: 60–62).

In Canada, the species has been reported from the South Saskatchewan River in Saskatchewan and Alberta; the Milk River drainage in the Cypress Hills region of Alberta and southwestern Saskatchewan; west in southern Alberta to the Flathead River system in the Waterton Lakes Region; north along the foothills of the Rockies in streams of the Saskatchewan River System to the North Saskatchewan River (Figure 3) [Scott 1957; Reed 1959; Willock 1969; Scott and Crossman 1973; Atton and Merkowsky 1983]. In British Columbia, the Mountain Sucker has been reported from the Columbia River system, the Similkameen and Tulameen rivers, and Otter and Wolfe creeks; and from the North Thompson (Fraser) River system (Figure 3) [Carl et al. 1967; Scott and Crossman 1973].

Protection

No specific measures are in place for the protection of this species in Canada. General protection, if required, could be afforded through appropriate sections of the Fisheries Act of 1867 (as amended to date). D. E. McAllister (Canadian Museum of Nature, Ottawa, Ontario: personal communication) and Scott and Crossman (1973) indicate that the species may be a rare member of the Canadian fauna.

The Mountain Sucker was listed as a species of special concern in the State of Washington by (Johnson 1987), but not by Williams et al. (1989).

Population Sizes and Trends

Information on this species is mostly limited to presence and absence data. The Mountain Sucker was virtually unknown in Canada prior to 1947 when Dymond (1947) recorded the species from the Cypress Hills Region of southwestern Saskatchewan. There is a previous mention by Eigenmann (1895) of *Catostomus griseus* [synonymous with *Catostomus platyrhynchus* (Smith 1966)] from the Swift Current Creek in Saskatchewan, as well as a 1927 ROM record from Belanger Creek (ROM 3891, Appendix III), and a 1928 University of Michigan Museum of Zoology record (UMMZ 164907) from Willow Creek near the border between Saskatchewan and Montana (Smith 1966). The species was first reported in Alberta and British Columbia in the 1950s (Scott 1957; Carl et al. 1959). Smith (1966) included a 1956 record from the Bow River (BC 56-516). Paetz and Nelson (1970) state that it was first taken in Alberta by R. B. Miller and C. Word in 1950 from the North Fork of the Milk River. It is doubtless endemic to the Missouri, Saskatchewan, Fraser and Columbia river faunas (Smith 1966; Cavander 1986; Cross et al. 1986; Crossman and McAllister 1986; McPhail and Lindsey 1986), and has probably occupied these systems since the last period of glaciation moving northward with the retreating ice front from Missouri and Cascadia refugia [*see* Hocutt and Wiley (1986) for more details on zoogeography and phylogeny]. They probably went previously unnoticed because of the lack of directed surveys and the inaccessibility of much of the habitat.

In some parts of its United States range it is abundant enough to be readily available as a bait fish. In some states it is used in the manufacture of pet food for feed in fur farming operations (Sigler and Miller 1963). It appears to be less abundant in the northern parts of the range (Scott and Crossman 1973), particularly in Washington, where it is considered to be a species of special concern (Johnson 1987). Mountain Suckers may no longer exist in the Missouri drainage of Nevada, although their former presence there is debatable (Smith 1966). The species is found in some abundance, however, in streams of the Great Basin. Goettl and Edde (1978) reported the Mountain Sucker to be one of the most abundant and widespread fishes found in a Colorado stream.

In Canada, Scott and Crossman (1973) suggested that the species was neither widely distributed nor abundant. McAllister (personal communication) also

FIGURE 3. Distribution of the Mountain Sucker, *Catostomus platyrhynchus*, in Canada based on sources cited in the text.

indicated that the species is probably rare in Canada based on is restricted range. However, collection records of the University of Alberta Museum of Zoology, the Canadian Museum of Nature, and the Royal Ontario Museum indicate that from one to 96 specimens were collected at various sites in Alberta during surveys, although it was more common to take less than 20 individuals at a given site. Willock (1969) states that the species is common in the Milk River drainage of Alberta and may be the only species found in the pseudo-alpine habitat of the Sweetgrass Hills. Henderson and Peter (1969) found the species to be abundant and widely dispersed in southern Alberta. B. Carveth (Institute of Animal Resource Ecology, University of British Columbia, Vancouver, B.C.; personal communication) indicates that, although records from British Columbia are scarce, the species is abundant where it has been found.

B. Carveth (personal communication) and others (Smith 1966; Scott and Crossman 1973) also indicate that it hybridizes readily with *Catostomus columbianus, Catostomus catostomus*, the Longnose Sucker, and *Catostomus commersoni*, the White Sucker, where the species are sympatric. This makes recognition difficult.

Habitat

The Mountain Sucker, like most species of the subgenus *Pantosteus*, are small catostomids typically associated with the cool waters of mountain streams in areas of moderate current which may occasionally occur in lakes or large rivers (Smith 1966). Their distribution and evolution is closely related to mountains; involving adaptation to cool waters, moderate to rapid currents, and rocky substrates. Mountains also are primary barriers, isolating populations and giving rise to variability between populations, through orogenic and tectonic processes. This has

made the taxonomy of the group and the resolution of generic status difficult (Smith 1966).

In Canada, collection records in the Royal British Columbia Museum, Canadian Museum of Nature, and the Royal Ontario Museum, indicate that its habitat is similar to that reported in northern parts of its United States' range. These fish are usually found in small mountain streams of less than 12 m width and 1 m depth with moderate to swift current, over bottoms ranging from mud, to sand, to gravel and boulders, but usually rubble. Water conditions vary from clear to roiled or turbid; daytime water temperature at collection sites is indicated as ranging from 10 to 28°C in summer and near 0°C in winter [*see* Reed (1962) for water conditions at collection sites in Saskatchewan]. Vegetation found at collection sites includes Pondweed (*Potamogeton* sp.), Muskgrass (*Chara* sp.) and algae, Cress (*Nasturtium* sp.), although macroscopic vegetation is not always present (Smith 1966).

Their occurrence in lakes and larger streams is rare, but they are known to occur in the Yellowstone River in Wyoming, Lower Green River Lake, Wyoming, and Bear Lake, Idaho (Smith 1966). However Erman (1986) found that the relative abundance of Mountain Suckers declined in Sagehen Creek, California, after impoundment of the stream to create a reservoir.

In a study of the species in Montana, Hauser (1969) observed that adults tend to favour areas of low velocity (0.5 m/sec) adjacent to pools with bank cover at depths of 1 to 1.5 m. Pierce (1966) noted that this species was usually more abundant below a warm spring. During spawning they utilize riffle areas below pools, returning to the deeper pools after spawning. Young fish, 20 to 35 mm long, prefer areas with moderate current at depths of 15 to 40 cm and are usually found close to an obstruction such as a large rock or submerged log. Larger fish may be found at the margin of runs, retreating to deeper water if disturbed, much the same as for the White Sucker (Stewart 1926). Fingerlings (35 to 135 mm) seem to prefer intermittent side channels with very little discharge and abundant aquatic vegetation at depths of 15 to 50 cm, but are also found in deeper pools (Smith 1966).

General Biology

Very little is known of the biology of the species in Canada and limited knowledge has been obtained elsewhere. Most of the information available on the species has been summarized by Smith (1966) and Scott and Crossman (1973). Most of the following was obtained from these sources as well as from Hauser (1969).

Reproduction: Spawning appears to occur in late spring or early summer when water temperature is above 10.5°C [average range 10.5 to 18.8°C: Scott and Crossman (1973)]. Spawning is usually in riffle areas adjacent to pools of swift to moderate mountain streams (*see* Smith 1966 for a summary of spawning times at various locations). The translucent, yellow eggs average 1.5 to 2.2 mm in diameter, and are demersal and adhesive (Hauser 1969; Scott and Crossman 1973). No nest is built, the eggs being scattered over the substrate. The incubation period is not recorded, but is probably in the neighbourhood of 8 to 14 days as reported for other suckers (Stewart 1926; Geen et al. 1966; Scott and Crossman 1973). Hauser (1969) reported spawning in Montana to occur in late June and early July and the earliest dates that fry were seen were 21 June in the Flathead Creek (water temperature 17 to 19°C) and 18 July in the East Gallatin River (water temperature 11 to 19°C).

Fecundity is related to fish length and age, generally older and larger fish bearing more eggs. Hauser (1969) estimated the number of eggs ranged from 990 (for a 131 mm female from Flathead Creek, Montana) to 3710 (for a 184 mm female from the East Gallatin River, Montana). Smaller (approximately 0.5 ×) recruitment eggs may also be found in the ovary providing further evidence of a short spawning season for this species; Hickling and Rutenburg (1936) demonstrated that a marked difference in size between mature and recruitment eggs indicates a short spawning season.

Age and Growth: Growth is slow in the environment of cold mountain streams and there is some evidence that the growth rate varies between streams (Hauser 1969). Some fry average 9 mm in July and may reach 30 to 36 mm by mid September. Ninety-five percent have formed the first annulus by mid-June of the following year at about 38 to 60 mm average length (Hauser 1969; Scott and Crossman 1973).

Growth is greatest during the first year, the rate of increase decreasing until the third year. After the third year the increment is small, but constant. Mean total lengths (TL) for various ages are given by Hauser (1969) as is an equation for the length-weight relationship.

Hauser (1969) also noted the females are generally larger than males and live longer, males living to about seven years of age and females to at least nine, as is generally true for most catostomids (Raney and Webster 1942; Harris 1962; Geen et al. 1966). Smith (1966) indicated that maturity was reached at the end of the second, and in some cases the first, year of life. However, Hauser (1969) found sex differences. Some females matured at age three and all females by age five. Some males matured by age two and all were mature by age four. Early maturing fish are probably also the faster growing fish of any age group (Alan 1959). Mature females range from 90 to

175 mm and males from 64 to 140 mm (Smith 1966; Hauser 1969).

Diet: Food items consist of algae, diatoms, small invertebrates and microscopic organic matter (Smith 1966). Plants, dipterous larvae and pupae, *Closterium* and filamentous algae are also important. Turbellaria, Ephemeroptera, Rotifera, and Plecoptera are infrequently eaten (Hauser 1969). The diet supports the hypotheses of Carl et al. (1967) that the horny edges of the jaw are an adaptation for scraping algae off rocks as diatoms and other algae are usually the most abundant food items found in stomach contents (Hauser 1969).

Movements: Little information is available on the movements of this species. Hauser (1969) indicated that adults move from deeper pools in late winter and spring to areas adjacent to the pools in moderate current (0.5 m/sec) and at depths of 1 to 1.5 m with rubble bottoms. During spawning the fish may be found in riffle areas below pools and after spawning they return to deeper pools with bank cover where they are often found in small schools separate from other catostomids. Smaller fish tend to be found around obstructions in areas of moderate current, but retreat to deeper areas if disturbed (Hauser 1969).

Parasites/Predators: The only parasite previously listed for the species was the trematode *Posthodiplostomum minimum* (Hoffman 1967). However, Evans et al. (1976), Palmieri et al. (1977), and Heckman and Palmieri (1978) recently found metacercariae of the eye fluke, *Diplostomum spathaceum*, to be widespread in Mountain Suckers and other fishes in Utah. The relative scarcity of parasites listed for the species probably reflects the degree of investigation rather than a low incidence of parasitic infestations.

Small fish may be utilized by other species, particularly by salmonids (Brook Trout, *Salvelinus fontinalis*, Brown Trout, *Salmo trutta*, and Rainbow Trout, *Oncorhynchus mykiss*,) which are often species associates (Goettl and Edde 1978; Erman 1986). Larger fish and spawning adults may be taken by birds and mammals (Scott and Crossman 1973), but their diet probably precludes competition with salmonids.

Behaviour/Adaptability: Very little is known of the behaviour of these fishes. The breeding behaviour (Hauser 1969) and feeding is probably similar to that of other catostomids (Stewart 1926; Brown and Graham 1953; Sigler and Miller 1963; Smith 1966) except that other species may consume more animal matter.

In many parts of the range the species is sympatric with other catostomids such as the White Sucker, Longnose Sucker, Tahoe Sucker (*Catostomus tahoensis*), Utah Sucker (*Catostomus ardens*), and *Catostomus discobolus* and hybrids between the species have been recorded (Smith 1966). Although *Catostomus platyrhynchus* is sympatric with *Catostomus columbianus*, in the Thompson, Similkameen and Columbia rivers, Smith (1966) indicated that hybrids between the two were not known. However, Carveth (personal communication) has found evidence that the two do hybridize to some extent although the Bridgelip Sucker is more a creature of lakes than streams in British Columbia and associations are not as common as for other catostomids.

Limiting Factors

Physical Factors: The distribution and evolution of mountain suckers is associated with mountains involving ecological adaptations to cool waters, swift currents and rocky substrates. Mountains also provide the major barriers isolating populations. In addition to separation of drainage basins, waterfalls may facilitate unidirectional gene flow. Ecological barriers may also occur due to the environmental differences in lower parts of streams where the water is warmer, more sluggish and turbid and the bottom substrates are different. Intermittent streams are also characteristic of mountainous areas. Within a given stream system a zone of intergradation may occur along a corridor many kilometres long, but only a few metres wide, and may combine with other factors to effect population isolation to varying degrees.

The linear nature of mountain stream environments has been the prime determinant of distribution, gene flow, and evolution in the subgenus. Since present distributional limits of this species (and other members of the subgenus) are not coincident with the possible limits defined by current hydrographic limits, the phyogeny is older than recent geographic patterns would suggest (Smith 1966). The early evolution and differentiation of *Pantosteus* probably took place during the Miocene and/or Pliocene in the vicinity of the highland areas of the eastern Great Basin, Colorado Plateau and ancestral Snake and Missouri river headwaters (Hunt 1956; Smith 1966; Minckley et al. 1986).

The subsequent history of *Pantosteus* is described by Smith (1966) with *Catostomus platyrhynchus* being best represented in the Great Basin and upper Missouri drainage. That two groups of populations are fairly distinct suggests a long period of isolation. There has been little differentiation of the widely separated populations of the Great Basin indicating a slow evolution. Populations of the Missouri drainage are more similar to populations of the Green, Snake, Columbia, and Sevier rivers and may have inhabited the western Wyoming area for a relatively long period of time, the eastward and northward spread occurring in the late Pliocene early Pleistocene

(Love et al. 1963; Smith 1966). Those of the upper Missouri, Milk and Saskatchewan drainages may represent undifferentiated postglacial derivatives which survived glaciation in a Missouri refugium (Cross et al. 1986; Minckley et al. 1986) and are probably still evolving and expanding their range in conjunction with stream rejuvenation and tectonic processes.

Catostomus platyrhynchus is distributed throughout the entire Columbia system and evidence for a preglacial existence suggests an earlier link with the Snake system (McPhail and Lindsey 1986). Populations below the falls on the Snake River are more similar to those of the Missouri system, while those above the falls have more affinity with those of the Great Basin (Smith 1966). With the retreat of the glaciers, local readvances occurred with the shifting network of drainage connections that is still occurring to some extent in interior British Columbia in the alpine and sub-alpine mountainous areas. In the Columbia system, the species occurs in sparse, scattered localities as morphologically differentiated forms implying that barriers to gene flow do exist (Smith 1966; McPhail and Lindsey 1986). Populations of the Fraser River system are most likely postglacial derivatives from the Columbia River (Smith 1966).

Habitat Perturbations: Erman (1986) provided evidence that impoundments may lead to the extinction of this species in reaches above reservoirs by changing the suitability of the habitat. The introduction of exotic species, agricultural diversions and riparian alterations have also been demonstrated to have negative imact on these fish (Goettl and Edde 1978). Industrial activity and habitat degradation resulting from mineral and fossil fuel exploration and development are also known to have deleterious effects (Goettl and Edde 1978).

Ecological Factors: Populations may be limited to some extent due to predation, particularly by salmonids which may forage on smaller individuals (Goettl and Edde 1978; Erman 1986). Birds and mammals may take some larger fishes during spawning (Scott and Crossman 1973); however, neither of these factors would appear to be leading to declines in most locations.

Competition with other catostomids could be limiting range expansion, but physical barriers are probably more important. *Catostomus platyrhynchus* is more highly specialized in its feeding and habitat requirements than the White or Longnose suckers or other species of *Pantosteus* where the ranges overlap (*see* Smith 1966; Hauser 1969; Scott and Crossman 1973). Dunham et al. (1979) have shown that competition with other sympatric catostomids leads to geographic variation in characters such as growth, feeding efficiency, body size and swimming mechanics. Smith (1966) indicated that fish from the same river system may show differences in such characters as width and shape of the caudal peduncle related to current flow and rate.

Special Significance of the Species

The species is fairly isolated in its Canadian distribution and is not a well-known member of the Canadian aquatic fauna. Although edible, it is too small to be of economic importance and has never been an important food or sport fish. In the United States, it is often used as a bait fish and as food for fur bearing mammals (Scott and Crossman 1973). Its diet precludes it from being a predator on other fishes. The taxonomy of the species and the genus is of interest because it reflects evolutionary zoogeographic events and their relation to geological processes.

Evaluation

Catostomus platyrhynchus appears to exist in many widely scattered locations in mountain streams of the Saskatchewan, upper Missouri, Columbia and Fraser river drainages in Canada. Although locally abundant at some localities they are not abundant in Canadian waters where they are at the northern fringe of the range. However, as Carveth (personal communication) indicates, we may not know the true extent of the range. It is probably still expanding in concert with long-term tectonic process. Widely scattered, reproductively viable populations, inherent genetic variability, and the lack of any present threat to most known localities augers well for the continued existence of the species in Canada. The construction of the Oldman River dam may, however, threaten populations in that river. Although perhaps rare in relation to other catostomids such as the White Sucker, the species does not appear to be in jeopardy and does not qualify for any COSEWIC category.

Acknowledgments

Financial support for this report was provided through World Wildlife Fund Canada, the Department of Fisheries and Oceans, and the Canadian Wildlife Service. E. J. Crossman and W. B. Scott kindly gave permission for the use of the illustration from Freshwater Fishes of Canada. Thanks are extended to the Canadian Museum of Nature, the Royal British Columbia Museum, the Royal Ontario Museum, to museums at the Universities of Alberta and British Columbia, and to Saskatchewan Parks and Renewable Resources for the provision of collection records and information. I wish also to acknowledge A. E. Peden of the Royal British Columbia Museum and W. Carveth of the University of British Columbia for their helpful comments received through the COSEWIC Fish and

Marine Mammals Subcommittee, and also all Subcommittee members for their helpful comments and review of the manuscript.

Literature Cited

Alan G. 1959. Connection between maturity, size and age in fishes. Reports of the Institute of Freshwater Research, Drottningham, 40: 5–145.

Atton, F. M., and **J. J. Merkowsky.** 1983. Atlas of Saskatchewan fish. Saskatchewan Parks and Renewable Resources Fisheries Technical Report 83–2: 108, 227.

Bailey, R. M. *[Chairman],* **E. A. Lachner, C. C. Lindsey, C. R. Robins, P. M. Roedel, W. B. Scott,** and **L. P. Woods.** 1960. A list of common and scientific names of fishes from the United States and Canada (Second edition). American Fisheries Society Special Publication Number 2: 1–102. Ann Arbor, Michigan.

Brown, C. J. D., and **R. J. Graham.** 1953. Observations on the longnose sucker in Yellowstone Lake. Transactions of the American Fisheries Society 83: 38–46.

Carl, C. G., W. A. Clemens, and **C. C. Lindsey.** 1959. The freshwater fishes of British Columbia. Third Edition British Columbia Provincial Museum Handbook 5. 192 pages.

Carl, C. G., W. A. Clemens, and **C. C. Lindsey.** 1967. The freshwater fishes of British Columbia. Fourth Edition British Columbia Provincial Museum Handbook 5. 192 pages.

Cavender, T. M. 1986. Review of the fossil history of North American freshwater fishes. Pages 699-724 *in* The zoogeography of North American freshwater fishes. *Edited by* Charles H. Hocutt and E. O. Wiley. John Wiley and Sons, Toronto, Ontario.

Cross, F. B., R. L. Mayden, and **J. D. Stewart.** 1986. Fishes in the western Mississippi drainage. Pages 363-412 *in* The zoogeography of North American freshwater fishes. *Edited by* Charles H. Hocutt and E. O. Wiley. John Wiley and Sons, Toronto, Ontario.

Crossman, E. J., and **D. E. McAllister.** 1986. Zoogeography of freshwater fishes of the Hudson Bay drainage, Ungava Bay and the Arctic Archipelago. Pages 53-104 *in* The zoogeography of North American freshwater fishes. *Edited by* Charles H. Hocutt and E. O. Wiley. John Wiley and Sons, Toronto, Ontario.

Dunham, A. E., G. R. Smith, and **J. N. Taylor.** 1979. Evidence for ecological character displacement in western American catostomid fishes. Evolution 33(3): 877–896.

Dymond, J. R. 1947. A list of the freshwater fishes of Canada east of the Rocky Mountains, with keys. Royal Ontario Museum of Zoology Miscellaneous Publication Number 1: 1–36.

Eigenmann, C. H. 1895. Results of explorations in western Canada and the northwestern United States. Bulletin of the U.S. Fisheries Commission (1894) 14: 101–132.

Erman, D. C. 1986. Long-term structure of fish populations in Sagehen Creek, California, USA. Transactions of the American Fisheries Society 115(5): 682–692.

Evans, R. S., R. A. Heckman, and **J. R. Palmieri.** 1976. Diplosomatosis in Utah USA. Proceedings of the Utah Academy of Sciences, Arts and Letters 53(1): 20–25.

Geen, G. H., T. G. Northcote, G. F. Hartman, and **C. C. Lindsey.** 1966. Life histories of two species of catostomid fishes in Sixteenmile Lake, British Columbia, with particular reference to inlet spawning. Journal of the Fisheries Research Board of Canada 23(11): 1761–1788.

Goettl, J. P., Jr., and **J. W. Edde.** 1978. Environmental effects of oil shale mining and processing. Part 1. Fishes of Piceance Creek, Colorado, prior to oil shale processing. Ecological Research Series Report, U.S. Environmental Protection Agency, Duluth, Minnesota. Report Number 27: 1–27.

Harris, R. H. D. 1962. Growth and reproduction of the longnose sucker, *Catostomus catostomus* (Forster), in Great Slave Lake. Journal of the Fisheries Research Board of Canada 19: 113–126.

Hauser, W. J. 1969. Life history of the Mountain Sucker, *Catostomus platyrhynchus,* in Montana. Transactions of the American Fisheries Society 98(2): 209–215.

Heckman, R. A., and **J. R. Palmieri.** 1978. The eye fluke disease diplostomatosis in fishes from Utah USA. Great Basin Naturalist 38(4): 473–477.

Henderson, N. E., and **R. E. Peter.** 1969. Distribution of fishes of southern Alberta. Journal Fisheries Reseach Board of Canada 26(3): 325–338.

Hickling, C. F., and **E. Rutenburg.** 1936. The ovary as an indicator of the spawning period in fishes. Journal of the Marine Biology Association of the United Kingdom 21(1): 311–318.

Hocutt, C. H., and **E. O. Wiley.** *Chairmen.* 1986. The zoogeography of North American freshwater fishes. John Wiley and Sons, Toronto, Ontario. 866 pages.

Hoffman, G. L. 1967. Parasites of North American freshwater fishes. University of California Press, Los Angeles, California. 486 pages.

Hunt, C. B. 1956. Cenozoic geology of the Colorado Plateau. U.S. Geological Survey Professional Papers 279. 99 pages.

Johnson, J. E. 1987. Protected fishes of the United States and Canada. American Fisheries Society, Bethesda, Maryland. 42 pages.

Love, J. D., P. O. McGrew, and **H. D. Thomas.** 1963. Relationship of latest Cretaceous and Tertiary deposition and deformation to oil and gas in Wyoming. Pages 196-208 *in* Backbone of the Americas, tectonic history from pole to pole. *Edited by* O. E. Childs and B. W. Beebe. American Association of Petroleum Geologists, Tulsa, Oklahoma.

McPhail, J. D., and **C. C. Lindsey.** 1986. Zoogeography of the freshwater fishes of Cascadia (the Columbia system and rivers north to the Sitkine). Pages 53-104 *in* The zoogeography of North American freshwater fishes. *Edited by* C. H. Hocutt and E. O. Wiley. John Wiley and Sons, Toronto, Ontario.

Minckley, W. L., D. A. Hendrickson, and **C. E. Bond.** 1986. Geography of western North American freshwater fishes: description and relationships to intracontinental tectonism. Pages 519-613 *in* The zoogeography of North American freshwater fishes. *Edited by* C. H. Hocutt and E. O. Wiley. John Wiley and Sons, Toronto, Ontario.

Paetz, M. J., and **J. S. Nelson.** 1970. The fishes of Alberta. The Queen's Printer, Edmonton, Alberta. 281 pages.

Palmieri, J. R., R. A. Heckman, and **R. S. Evans.** 1977. Life history and habitat analysis of the eye fluke *Diplostomum spathaceum,* Trematoda: Diplostomatidae in Utah USA. Journal of Parasitology 63(3): 427–429.

Pierce, B. E. 1966. Distribution of fish in a small mountain stream in relation to temperature. Proceedings of the Montana Academy of Science 26: 1–76.

Raney, E. C., and **D. A. Webster.** 1942. The spring migration of the common white sucker, *Catostomus catostomus commersonnii* (Lacépède), in Skaneateles Lake Inlet, New York. Copeia 1942(3): 139–148.

Reed, E. B. 1959. A biological survey of the principal rivers of the Saskatchewan River system in the Province of Saskatchewan, 1957 and 1958. Saskatchewan Parks and Renewable Resources Fisheries Technical Report 59-1: Table 24.

Reed, E. B. 1962. Limnology and fisheries of the Saskatchewan River in Saskatchewan. Fisheries Branch Saskatchewan Department of Natural Resources Fisheries Report Number 6. 48 pages.

Robins, R. C. [*Chairman*], **R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea,** and **W. B. Scott.** 1980. A list of common and scientific names of fishes from the United States and Canada (Fourth edition). American Fisheries Society Special Publication Number 12. 174 pages. Bethesda, Maryland.

Scott, W. B. 1957. Distributional records of fishes in western Canada. Copeia 157(2): 160–161.

Scott, W. B., and **E. J. Crossman.** 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada, Bulletin 184. 966 pages. Ottawa, Ontario.

Sigler, W. F., and **R. R. Miller.** 1963. Fishes of Utah. Utah State Department of Fish and Game, Salt Lake City, Utah. 203 pages.

Smith, G. R. 1966. Distribution and evolution of the North American catostomid fishes of the subgenus *Pantosteus*, genus *Catostomus*. Miscellaneous Publications of the Museum of Zoology, University of Michigan, Number 129. 132 pages.

Snyder, D. E. 1983. Identification of catostomid larvae in Pyramid Lake and the Truckee River, Nevada. Transactions of the American Fisheries Society 112(2B): 333–348.

Stewart, N. H. 1926. Development, growth and food habits of the white sucker, *Catostomus commersonnii*, LeSeur. Bulletin of the U.S. Bureau of Fisheries 42: 147–184.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and **J. E. Deacon.** 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries 14(6): 2–20.

Willock, T. A. 1969. Distributional list of fishes in the Missouri drainage of Canada. Journal of the Fisheries Research Board of Canada 26(6): 1439–1449.

Accepted 31 May 1991

Status of the Harbour Porpoise, *Phocoena phocoena*, in Canada*

David E. Gaskin

Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1

Gaskin, David E. 1992. Status of the Harbour Porpoise, *Phocoena phocoena*, in Canada. Canadian Field-Naturalist 106(1): 36–54.

The Harbour Porpoise, *Phocoena phocoena*, occurs in both major oceans of the temperate northern hemisphere; it is resident in, or migratory into, the marginal seas except for the Mediterranean and is a summer visitor to the productive fringes of the Arctic Ocean. No surveyed census estimates of population sizes are available in Canadian coastal waters other than for the Bay of Fundy-northern Gulf of Maine, which has a seasonal population of about 4000 to 8000 animals, with a peak period of residency from late July to mid-September. This population, like those on the west coast, in the St. Lawrence and off Newfoundland, is believed to make a seasonal migration of a rather diffuse nature. Although generally regarded as a common species, it is evidently in decline in many parts of its total range. While factors such as increased human disturbance of coastal regions may be implicated in this decline and increased contamination of the environment may be another factor, the most likely reason for decreasing numbers is the toll exacted by incidental catches in fishing gear, especially groundfish gillnets, coupled with the animal's very limited reproductive flexibility.

Le Marsouin commun, *Phocoena phocoena*, vit dans les eaux des deux grands océans de l'hémisphère nord tempéré; on le trouve, à titre de résident ou en période de migration, dans les mers bordières, à l'exception de la méditerranée, et il visite pendant l'été les zones limitrophes productives de l'océan Arctique. On ne dispose d'aucune estimation de ses effectifs dans les eaux côtières du Canada, si ce n'est de celles de la baie de Fundy et du golfe du Maine nord où sa population saisonnière se situe entre 4000 et 8000 individus environ, avec une période de pointe de fin juillet à mi-septembre. Cette population, comme celles de la côte ouest, du Saint-Laurent et des eaux au large de Terre-Neuve, semble effectuer une migration saisonnière de nature assez diffuse. Bien que généralement considéré comme espèce commune, il est évident que le marsouin commun est en déclin dans bon nombre de secteurs de son aire de répartition totale. Certains facteurs, notamment une plus grande perturbation des régions côtières due aux activités humaines, et une contamination accrue de l'environnement, peuvent contribuer à ce déclin, mais la raison le plus probable réside dans les captures accidentelles avec les engins de pêche, surtout les filets maillants à poissons de fond, de pair avec et la faible capacité d'adaptation reproductive de cette espèce.

Key Words: Harbour Porpoise, le Marsouin commun, *Phocoena phocoena*, Cetacea, Odontoceti, Phocoenidae, marine mammals, endangered species.

The adult Harbour Porpoise, *Phocoena phocoena* (Linnaeus 1758), attains, on average a length of about 1.6 m and a weight of about 50 kg (Figure 1). The snout is bluntly pointed, with no delineated "beak". The dorsal fin is relatively small and triangular, often with an anterior ridge of tubercles. The dorsal surface is dark grey with purplish reflections in life. The chin, variable areas of the flanks, and the ventral surface are white, usually flecked with grey near the dorsal fin. The flippers, flukes and dorsal fin are all dark grey, and there is usually a grey stripe from the eye to the anterior angle of the flipper.

The Harbour Porpoise has an almost circumpolar distribution in the temperate regions of the northern hemisphere (Figure 2). Although most frequently encountered in coastal waters it also occurs over adjacent offshore shallows (e.g., Georges Bank, the Grand Bank, and the Dogger Bank). Because populations occur around isolated land masses such as Iceland and the Faeroe Islands in the Atlantic (Saemundsson 1939; Gaskin 1984), and the scattered Aleutian Islands in the North Pacific-Bering Sea (Leatherwood et al. 1983), porpoises must occasionally cross wide expanses of open ocean, probably following the rich pelagic feeding zones created by the ocean polar fronts. Perhaps the colonizations of areas such as Iceland resulted when the northward retreat of the semi-permanent ice edges in the late Pleistocene was accompanied by a corresponding northward movement of the polar front (and its associated fauna) which, during the glacial stadials, was much further south than it is now. There are few confirmed records of this species away from the continental shelf; during CeTAP (Cetacean and Turtle Assessment Program) surveys off the northeastern United States coast for example, only about 0.6% of

*Report accepted by COSEWIC 9 April 1991. Threatened status assigned to the Northwest Atlantic population 10 April 1990 and reconfirmed 9 April 1991; Insufficient scientific information for status designation for the Northeast Pacific population.

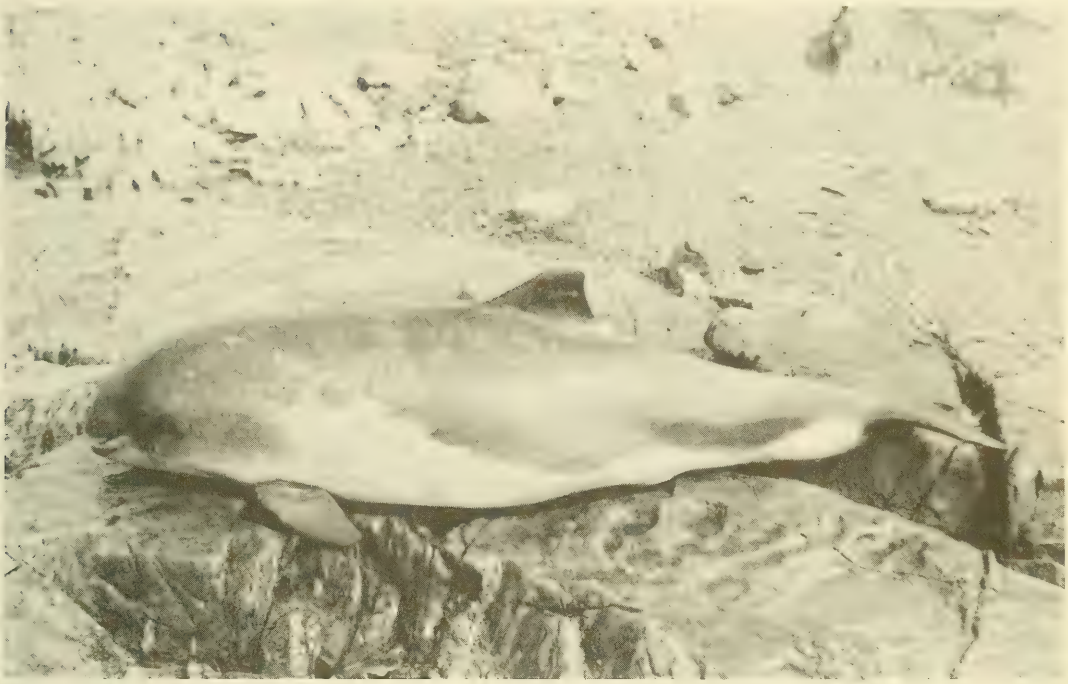


FIGURE 1. Photograph of a female Harbour Porpoise (89 cm), taken 14 August 1970 by the author.

all Harbour Porpoise sightings were outside the 2000 m depth contour (Winn 1982). Recently however, Stenson and Reddin (1990) reported Harbour Porpoises over deep water in the Newfoundland Basin and the Labrador Sea. The species is notoriously difficult to sight at any distance in even moderate seas, so it can be easily overlooked by inexperienced observers.

Gaskin (1984) summarized the hemispheric distribution and zoogeography of the Harbour Porpoise based on information collected from 1974 to 1983. The article supplemented the extensive bibliographies provided earlier by Gaskin et al. (1974), Mitchell (1975), Prescott and Fiorelli (1980) and Prescott et al. (1981). More recent information can be found in the volume of abstracts from the proceedings of a conference on cetacean-fishing gear interactions held in La Jolla, California in October 1990, published by the International Whaling Commission (IWC 1990) and in articles by Barlow (1987, 1988), Broekema and Smeenk (1987), Calambokidis (1986), Diamond and Hamon (1986), Gaskin et al. (1984), Gaskin et al. (1985), Gaskin and Watson (1985), Hanan et al. (1986), Kinze (1985a, 1985b), Lansdown (1987), Noldus and de Klerk (1984), Read and Gaskin (1985, 1988), Schulze (1987), Smith and Gaskin (1983), Smith et al. (1983), van Kreveld (1987), Watson and Gaskin (1983), Watts and Gaskin (1985, 1989), Worthy et al. (1987), Yasui and Gaskin (1986) and Yurick and Gaskin (1987, 1988). The monograph by Schulze (1987) has a particularly extensive bibliography, including some European references which may be unfamiliar to many North American workers, and the review by van Kreveld (1987) also contains a number of useful document references often overlooked

FIGURE 2. Global distribution of *Phocoena phocoena* shown by stippled zones.

in North American abstracts or not represented in libraries here.

Distribution and Subpopulations

Three major isolated populations exist; in the North Pacific, in the North Atlantic and in the Black Sea-Sea of Azov (Figure 2). These are distinguishable on cranial meristic and morphometric features (Yurick and Gaskin 1987). Based on data presented by Tomilin (1957) the Black Sea-Sea of Azov animals probably represent a single population with no discernible sub-groups. This population may have been reduced to a critically low level in recent years by over-exploitation, initially by fishermen from the USSR, Bulgaria and Turkey, and more recently, by Turkey alone (IWC 1983, 1984). Yurick and Gaskin (1987) presented evidence for statistically significant cranial differences between the eastern and western North Atlantic populations of the Harbour Porpoise, and indicated that there were also inconclusive data suggesting further segregation of the eastern North Atlantic population into regional sub-populations. Kinze (1985a) concluded that there were highly significant differences in metric and non-metric cranial characters between animals from the Baltic and the Dutch coast, but not between those from the Baltic and the northeastern North Sea. The present author, however, has some reservations about these results, because Kinze's regressions do not appear to have been age-corrected and may have been influenced by age-specific catch biases in different samples.

Gaskin (1984) reviewed the somewhat tenuous data concerning possible latitudinal sub-population segregation of *Phocoena phocoena* in the eastern North Pacific. The species has been recorded from the MacKenzie River delta, Northwest Territories (van Bree et al. 1977), to Los Angeles Harbour. The occurrence of the Harbour Porpoise in the Beaufort Sea is probably not exceptional. Some *de facto* segregation appears probable; studies in Prince William Sound, Glacier Bay and the Copper River estuary (Hall 1979; Matkin and Ray 1980; Taylor and Dawson 1983) point to calving in these waters, and some animals present in all months of the year. Similarly, some animals appear to be resident along the coast of California throughout the year. Information on ratios of DDE/PCB and HCB/DDE presented by Calambokidis (1986) provides supporting evidence for segregation into subpopulations along this coast. Along the coasts of the northwestern states and British Columbia the species were formerly regarded as less common south of Washington State than further north (Fiscus and Niggol 1965). Gaskin (1984), after Yurick (1977), tentatively proposed two working topographic sub-divisions for the western seaboard; the Bering Sea, and the coast from the Gulf of Alaska to Los Angeles harbour. North-south and inshore-offshore movements are to be expected in both these speculative sub-populations, but given the seasonal "territoriality" recorded for some individual Harbour Porpoises (Gaskin and Watson 1985), it is likely that some degree of latitudinal segregation is present.

The West Coast of Canada

Within British Columbian waters the Harbour Porpoise was formerly considered to be common up to 20 miles from shore in all areas (Pike and MacAskie 1969). The species appears to have been less commonly sighted in the last two decades in the coastal waters of British Columbia (H. D. Fisher *in litt.* 1978; I. McTaggart-Cowan, Canadian Committee on Whales and Whaling, 3919 Woodhaven Terrace, Victoria, B.C., personal communications), and in the adjacent "Washington Sound" region (Flaherty and Stark 1982). Fisher and McTaggart-Cowan did not collect quantitative information however.

As far as can be determined, the only concrete distributional data for the Harbour Porpoise on the coast of British Columbia consist of some strandings collected by the Royal British Columbia Museum, and a few records from 1987 published by Baird et al. (1988) and regular sightings at one locality by Alex Morton (Echo Bay, Simoon Sound, B.C., personal communication). The localities are shown in Figure 3.

The Estuary and Gulf of the St. Lawrence

The only published account of the distribution and catches of Harbour Porpoises in the St. Lawrence region is that by Laurin (1976). Recently valuable information has been provided by Béland (1988) and Béland et al. (1987), and a survey of incidental captures in Quebec waters is currently being undertaken by the Department of Fisheries and Oceans, Canada. The species was frequently sighted around the Magdalen Islands in the 1950s [H. D. Fisher, (formerly of) Department of Zoology, University of British Columbia, Vancouver, B.C., personal communication], and the author observed Harbour Porpoises off the eastern coast of P.E.I. in July 1974. These data are summarized in Figure 4. Although stranding records often reflect only effort variations in data collection, this figure demonstrates that we do not even know if the species is present in most of the Gulf. It also indicates where even cursory studies would be of value. The westerly limit of this species appears to be the mouth of the Saguenay River; possible reasons for this were discussed by Sergeant (1978).

One of the areas of summer concentration of the Harbour Porpoise in the Gulf of St. Lawrence is Jacques Cartier Passage, between Anticosti Island and northern Quebec. R. Sears and W. Hoek (*in litt.* 1988), reported seeing large numbers all along this region of the North Shore, with peak abundance in late summer and fall.

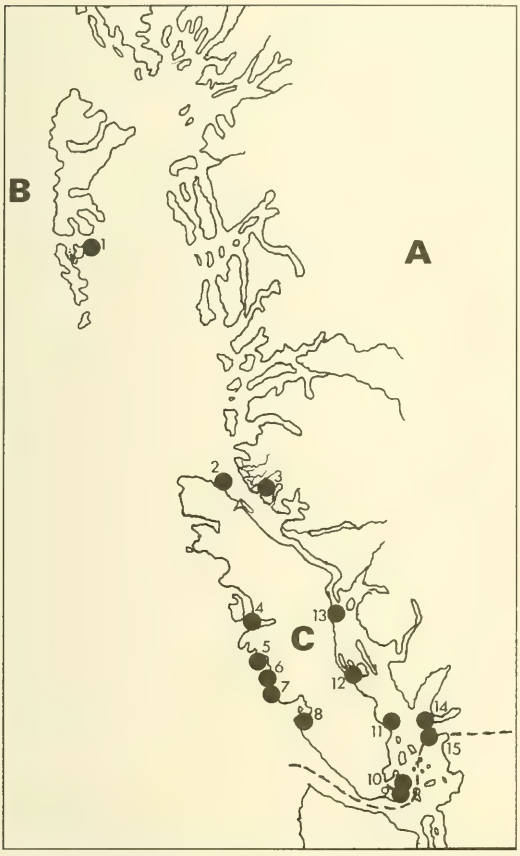


FIGURE 3. Distribution of records of *P. phocoena* on the west coast of Canada; with the exception of Simoom Sound, these represent confirmed strandings only. Major geographical features: A. British Columbia, B. Queen Charlotte Islands, C. Vancouver Island. Specific localities: 1. Sandspit, Morseby Island, 2. Port Hardy, 3. Echo Bay, Simoom Sound, 4. Nootka Island, 5. Flores Island, 6. Tofino, 7. Long Beach, 8. Bamfield, 9. Clover Pt, Victoria, 10. McNeill Beach, Victoria, 11. Gabriola Island, 12. Little Qualicum River, 13. Campbell River, 14. Vancouver, 15. Tsawassen. These records are collated from data supplied by Baird, Nagorsen and Morton (*see* Acknowledgments).

Baffin Island to Newfoundland

The Harbour Porpoise is commonly recorded on the Greenland side of Davis Strait and Baffin Bay between 61°–67°N (Figure 2) from spring to summer (Kapel 1975, 1977), with the most northerly record probably that from Upernavik at 72°N. On the Canadian side of the Bay, the northernmost limit appears to be Cape Aston at 70°N. Records are more sparse (Mercer 1973) on the Canadian coast because the fishing activity is much less and ice conditions will often keep cetaceans far from land. Furthermore, it is only in recent years that any attempts have been made to collect information on small odontocetes, other than the Narwhal (*Monodon monoceros*) and White Whale (*Delphinapterus leucas*), in those waters. The Harbour Porpoise appears to be distributed, at least in certain months, throughout the coastal shelf waters of Labrador and eastern and southeastern Newfoundland (Lien 1983, 1989), and in deeper waters of the Labrador Sea and the Newfoundland Basin (Stenson and Reddin 1990).

The Atlantic Coast of Canada — Cape Breton to southern New Brunswick

This is one of the most-studied populations of the species; a continuous programme of research by the University of Guelph has been in operation since 1969, and earlier work was carried out by Fisher and Harrison (1970). More recently, United States surveys have included some transects in Canadian waters. The species probably occurs throughout this area in small numbers in all months of the year. There appear to be no records of significant concentrations off Cape Breton other than an unpublished observation by G. A. Mertens (Lunenburg, Nova Scotia, personal communication). In University of Guelph surveys in the 1970s the Harbour Porpoise was not found to be nearly as abundant in the summer months along the Atlantic coast of Nova Scotia as in the Bay of Fundy and the northern Gulf of Maine (Figure 5). The majority of the latter animals may move offshore to Georges Bank and adjacent shallows in the autumn; some occur inshore during the winter from New Hampshire to New York, and sometimes as far south as North Carolina (Gaskin 1984) [*see* section on Species Movement].

Protection

For many years the Harbour Porpoise was afforded no protection at all in Canadian waters; despite this, directed hunting for the species was never extensive in modern times. The Harbour Porpoise, like most small cetaceans other than White Whale and Narwhal, went unprotected in Canada because it did not fall within the scope of the Whaling Convention Act of Canada, which was in force until 1982. When Canada voluntarily withdrew from the International Whaling Commission, the Convention Act was repealed by Parliament, which then passed into law a substitute set of more broadly defined Cetacean Protection Regulations. These were promulgated in 1982 under the Fisheries Act of Canada, and included all cetaceans. The animal was taken for meat in Newfoundland, and still is in some areas according to Lien et al. (1987), but only in the form of salvaged carcasses from gill nets. The Atlantic coastal communities of Passamaquoddy and Micmac Indians traditionally hunted porpoises, but the practice has almost, if not completely, died out. One hunter in the Beaver Harbour region took the species

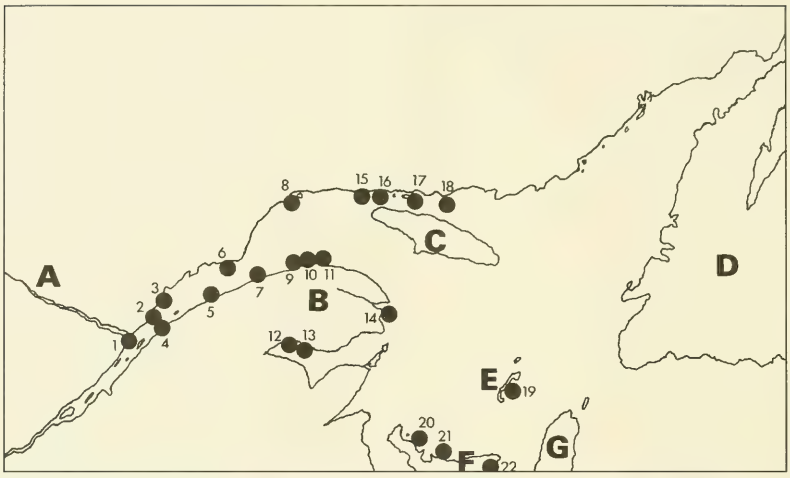


FIGURE 4. Distribution of records of *P. phocoena* in the St. Lawrence region; these records are of strandings and confirmed incidental catch reports. Major geographical features: A. Saguenay River, B. Gaspé Peninsula, C. Anticosti Island, D. Western Newfoundland, E. Magdalen Islands, F. Prince Edward Island, G. Cape Breton Island. Specific localities: 1. Baie Ste-Catherine, 2. Les Escoumains, 3. St. Paul-du-Nord, 4. St. Simeon, 5. St. Flavie, 6. Godbout, 7. Les Mechins, 8. Brochu, 9. Marsoui, 10. Mont-Louis, 11. Petite-Vallee, 12. Carleton, 13. Maria, 14. Forillon, 15. Longue-Pointe, 16. Mingan, 17. Havre Saint-Pierre, 18. Baie-Johan-Beetz, 19. Grande Entree, 20. Hardy's Channel, 21. Cavendish, 22. Georgetown. These records are taken from Laurin (1976) and more recent data summaries provided by P. Béland et al. (1987).

to provide meat for his mink farm in the 1950s and early 1960s (Fisher, personal communication). Indians from the Pleasant Point Reserve in northern Maine have sporadically hunted Harbour Porpoises in Canadian waters into the 1980s.

Population Sizes and Trends

Pacific Coast

Barlow (1988), using line transect methods during four ship surveys covering 6590 km in September 1984 and May 1986, estimated the total population size of the Harbour Porpoise on the coasts of California, Oregon and Washington as slightly under 50 000 (49 862 ± 8891). He noted factors which he believed, could have led to this being an underestimate. It is also possible to identify factors, especially latitudinal changes in densities, which could result in it being an overestimate. There is a strong possibility of latitudinal shifts in population centres during the course of the year.

Nevertheless, if Barlow's estimate of mean density is accepted as a working value and in the process of estimating an overall approximate multiple for shelf area one eliminates from consideration, as did both Barlow (1988) and Watts and Gaskin (1985), narrow shelf regions with strong currents off Vancouver Island, then western Canadian waters might, at least initially, have sustained a population of some 15 000 to 20 000 animals. This estimate should be regarded with scepticism. Because the species occurs along the coasts of southern Alaska, British Columbia, Washington, and Oregon, the impact of seasonal latitudinal shifts on this estimate are unknown. No recent surveys have been made in western Canadian coastal waters that could be used for crude population estimates, nor are there any data on incidental catch levels or impact.

Atlantic Coast

Gaskin (1977) estimated a population of about 4000 in the Bay of Fundy-northern Gulf of Maine, and Prescott et al. (1981) reported from 2603 to 3456 for approximately the same region. Using more rigorous techniques Gaskin et al. (1985) estimated the August population in the western Bay of Fundy as 3056 ± 1661 in an area of 1969 km^2. Watts and Gaskin (1985) estimated the peak population in the Outer Quoddy region only as 1022, closely comparable to 1018 to 1270 for the shipboard surveys through the same area by Gaskin et al. (1985). The latter concluded that the total population for the lower Bay of Fundy and approaches could be as high as 7000 to 8000 animals in August, i.e., nearly twice as many as calculated by Gaskin (1977). It should be borne in mind, however, that density estimates which take into account the large "empty" area in the

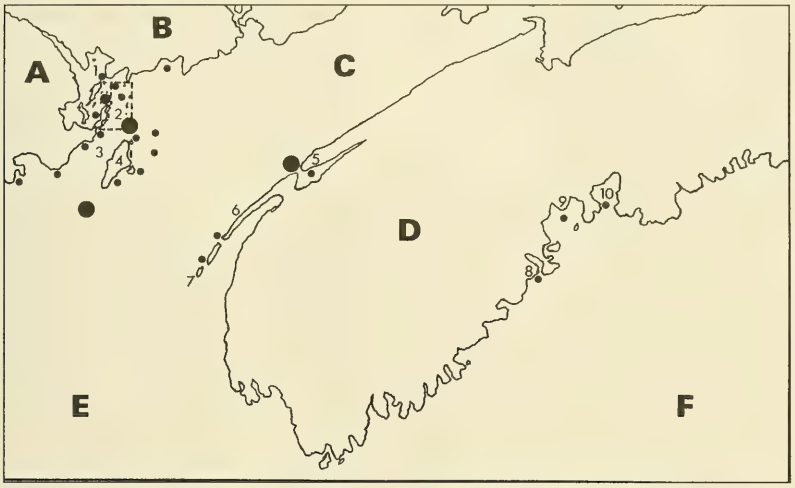


FIGURE 5. Distribution of records of *P. phocoena* in the Atlantic region; these records are largely based on quantitative field surveys between 1971-1986. Major geographical features: A. Maine, B. New Brunswick, C. Bay of Fundy, D. Nova Scotia, E. Gulf of Maine, F. Atlantic Ocean. Specific localities in text: 1. Inner Quoddy Region, this comprises Passamaquoddy and Cobscook Bays to the north and west, and Letite Passage, the Western Isles and Head Harbour Passage to the north and east, 2. The Outer Quoddy region, 3. Grand Manan Channel, 4. Grand Manan Island, 5. Digby Gut and Annapolis Basin, 6. The Digby Neck, 7. Brier Island. The closed circles provide a rough representation of densities encountered in summer only. While the species is relatively scarce in the upper Bay of Fundy, the lack of data points on most of the oceanic coast of Nova Scotia indicates only that no surveys have been made.

lower central Bay of Fundy where Harbour Porpoises are consistently absent for nearly two thirds of the summer (Kraus and Prescott 1981), will yield numbers only in the 4000 to 6000 range.

Kraus et al. (1983) surveyed the coast of Maine from Port Clyde to Cutler in July 1982 and obtained a minimum strip-census estimate of 7956. At this time of year porpoise density would not have attained its maximum in the lower Bay of Fundy. It seems likely that many of the animals seen off Maine would shift northwards by August, since surveys in the Boothbay Harbor region of southern Maine in 1971 and 1972 did not find large numbers of animals there (Gaskin, unpublished data). The CeTAP aerial surveys (Winn 1982) recorded only 1800 from Cape Hatteras to the Gulf of Maine, but this has to be a minimum estimate, given the small proportion of time this animal spends at the surface (Watson and Gaskin 1983) and that in an experiment, only 14% of porpoises sighted by land-based observers were picked up by an aerial survey crew (Prescott et al. 1981).

The calculated population size of 7956 ± 1327 to 15 300 ± 2552 (extrapolated by area from the 1982 strip census above) for the eastern seaboard from southern Maine to the New Brunswick border and lower Bay of Fundy would seem a reasonable working estimate. Even within "high-density" regions, however, there still areas which consistently have few animals. Furthermore, significant distributional shifts can occur, and Kraus et al. (1983) may have overestimated the offshore component beyond the 50 fathom contour. It would be wiser, from the management and conservation point of view, to accept the lower numbers as conservative population estimates. There are no published population estimates for the waters of Labrador, Newfoundland, or the Gulf of St. Lawrence (Gaskin 1984).

It is possible, however, based upon the well-known relationship of three fisheries population statistics, C (catch size), P (population size) and F (fishing mortality), to attempt some crude estimates of Harbour Porpoise population sizes in the Gulf of St. Lawrence and in the coastal waters of Newfoundland, as suggested to the author by J. Brazil (Newfoundland Department of Environment and Lands, Wildlife Division, St. John's, Newfoundland, personal communication). The necessary, and probably unrealistic, assumptions for this exercise include: 1) that Harbour Porpoise densities in the Fundy region (where the best data are available), are more or less equivalent to those in the St. Lawrence and around eastern Newfoundland, 2) that the relative catching power of gill nets is also more or less

equivalent per unit set in each region, 3) that gill net distribution densities are equivalent, and 4) that all segments of the porpoise populations have equal catchability.

For Fundy we have several surveyed estimates of population size for a range of sizes of areas, a reasonably well-defined value for the annual incidental catch and from this we can derive a rough estimate for F. In the other regions we have some preliminary estimates for C, and by using the Fundy approximation for F, can derive crude values of P.

As indicated above, Gaskin et al. (1985) estimated the August population of Harbour Porpoises in the western Bay of Fundy to be about 3.0 ± 1.6 thousands, and Read and Gaskin (1988) reported that the annual catch was of the order of 105 ± 10 animals. This yields a range of incidental mortalities from 2.01 to 4.79%. If, as is believed, this population is contiguous with that in the Gulf of Maine, then the population size estimates given by Kraus et al. (1983) for the whole region, and the catch levels estimated by Polacheck (1989) or Kraus et al. (1990) for the whole region, can be used also. These yield mortality values ranging from 280 in a maximum population of 17 852 (1.57%) to 800 or 1000 in a minimum population of 6629 (12.07 to 15.08%), with an approximate average of about 640 out of 12 240 (5.23%). If the population estimates given by Watts and Gaskin (1985) for just the Inner Quoddy region are used in conjunction with the gill net catches from southwestern Fundy only, then we have catches of 95 to 115 in 1022 to 1270 (7.4 to 11.3%). Given the accumulated evidence of changes in characteristics of this population (*see* later sections on Reproductive Biology and Limiting Factors), it seems reasonable to reject values of less than about 4% which would probably not lead to any significant changes (Woodley and Read 1991), as well as the highest which, given the duration of the gill net fisheries in many areas, should have already led to population collapse. For purposes of extrapolation to the other two regions, I therefore select a value for F of 5.23%, derived from the averages in the data collected from the Gulf of Maine and the Bay of Fundy by Kraus et al. (1983) and Polacheck (1989). The minimum value for C in the Gulf of St. Lawrence is 623, and the maximum perhaps 1500 (Fontaine et al. 1990); these yield crude values for population size within a range of 11 900 to 28 800 animals.

For these coasts of Newfoundland and Labrador, Lien (1989) had an approximate maximum catch estimate of about 3000 porpoises per annum; using his estimated average of 1800 yields values for P from 34 415 to 57 360, if such catch levels were being sustained. J. Lien (Memorial University of Newfoundland, St. John's Newfoundland, personal communication) noted, however, that incidental catches and sightings were low in the spring and summer of 1990, leading him to believe that a population crash had already started to occur in Newfoundland waters. There are so many imponderables in the data from these regions at present that such population estimates for Harbour Porpoises must be used with the greatest caution.

Habitat

There is no doubt that the Harbour Porpoise is closely tied, in distributional terms, to the major pelagic schooling fish which comprise the bulk of their diet. The Harbour Porpoise is found in the northern hemisphere only, for practical purposes within waters of about 5 to 16°C. Only a relatively small percentage of the total population seems to penetrate Arctic waters of 0 to 4°C. Even in the Black Sea–Sea of Azov, winter temperatures in the southern part are probably 4° to 8°C in most years, and although summer temperatures of up to 25°C are common near the Turkish coast, these are not typical of the upwelling areas near the Crimea where the species probably concentrates during much of the summer. While normally considered an open sea and ocean channel animal the Harbour Porpoise commonly penetrates rivers and must experience salinities down to about 15‰ in the Black Sea, and much less in the rivers. It rarely occurs with any frequency in waters less than about 7 to 10 m in depth, unless the bottom is sandy and the current weak; however, it is not common in such conditions because suitable food is usually not abundant. It is generally not often recorded in waters deeper than about 125 m (Barlow 1987, 1988). It is often seen feeding on pelagic schooling fish such as herring and mackerel, but also takes a proportion of hake, squid and octopus in deeper waters of the Bay of Fundy, where it has been frequently caught in groundfish gill nets as deep as 100 m (Read and Gaskin 1988).

The Harbour Porpoise has been recorded in southern New Brunswick waters during all months of the year; surface temperatures range from 1 to 3°C in winter to 14 to 15°C in late summer-early fall. Only a few animals appear to winter in the region, but the temperature range encountered may be close to the tolerable lower limit for the species, even if they can increase their feeding rate (Yasui and Gaskin 1986). While the Harbour Porpoise migrates up to latitude 70°N in the eastern waters of Baffin Bay in August, the sea surface temperatures there can range as high as 4°C in that month, and close to 8°C in the southern part of Davis Strait at 61 to 65°N (U.S. Hydrographic Office 1958). The bulk of the Harbour Porpoise population which uses the outer Bay of Fundy during the summer and fall begins to enter the region when surface temperatures are between 8 to 10°C, and abundance usually continues to increase as temperatures rise from 10 to 15°C, depending on local oceanographic conditions, with salinities from

32 to 34‰. This probably does not imply some kind of physiological limitation, because a Harbour Porpoise in the Otaru Aquarium in Hokkaido, Japan, lives in a tank with several Finless Porpoises (*Neophocoena phocoenoides*) at 22°C with no sign of difficulties. Rather, the sea temperatures correlate quite closely with the preferred temperature range of the Harbour Porpoise's main prey in this region, the Atlantic Herring (*Clupea harengus*).

Watts and Gaskin (1985) were surprised to find that relative abundance of porpoises in the Bay of Fundy during August was *inversely* correlated with surface temperature distributions, probably as a result of association of Atlantic Herring with vertically mixed waters. Because such zones are generated in this region by tidal upwelling processes, they are usually significantly cooler at the surface than the adjacent stratified waters. In general, the Harbour Porpoise tends to be associated with certain oceanographic phenomena, such as the zones indicated above, or isolated upwellings, rather than with any particular segment of a parametric range. Zooplankton such as *Calanus finmarchicus* which are a major prey item for Atlantic Herring (Brawn 1960; Iles 1979; Jovellanos and Gaskin 1983), are concentrated along coastal frontal interfaces. In such areas zooplankton can be 752 more abundant than outside the frontal zone (Pingree et al. 1974). In the interface zones of the Bay of Fundy *Calanus finmarchicus* makes up 85 to 96% of the total 2 to 4 mm plankton (Murison and Gaskin 1989). It is not surprising therefore, that Smith and Gaskin (1983) found a strong correlation between copepod density and relative porpoise abundance during their habitat index analyses.

Harbour Porpoises are usually scarce in areas without significant coastal fronts or topographically generated upwellings. On the eastern coasts of Nova Scotia and Prince Edward Island, University of Guelph surveys found them to be far less abundant than in the Bay of Fundy. Yet, even in these areas, a few Harbour Porpoises could usually be found in the lee of an island or archipelagic intrusion where eddies and turbulence provide a zone for passive concentration of zooplankton and usually a feeding and resting place for planktivorous fish. Over relatively featureless, shallow sandy bottoms, or over wide channels with mud bottoms and uniform depth such as the Grand Manan Channel, the species is again usually scarce.

Kraus and Prescott (1981: Figure 17), illustrated survey data for Harbour Porpoises in the lower Bay of Fundy and upper Gulf of Maine from mid-June to late October 1980. Their figures clearly show a large area to the east and southeast of Grand Manan, encompassing much of the central region of the lower Bay, in which Harbour Porpoises were almost completely absent, except for the first half of July. R. G. B. Brown, S. Barker, and the author carried out extensive seabird and marine mammal surveys in the same region in 1974 and 1975, with the same results. Only one animal was recorded in the offshore zone, despite the fact that porpoises were locally abundant in Digby Gut and the passages that cut through Digby Neck in western Nova Scotia. In each case, porpoises were concentrated in what might be called "bottlenecks" for pelagic fish movement; zones where the probability of contact with prey was greatly enhanced. Gaskin and Watson (1985) observed porpoises move directly from one such point to another when foraging off the eastern side of Deer Island in southern New Brunswick. In general, the three main concentration areas in the Fundy region are associated with either major passages, or a large discrete bank with turbulent upwellings (Figure 4).

Variation in abundance can still be quite striking even when one examines two areas where similar topographic and oceanographic conditions prevail. There is little doubt that Harbour Porpoises have the ability to adjust their local distribution patterns by continuously monitoring their environment visually and acoustically and on the basis of previous experience. Watts and Gaskin (1985), observed that porpoises were nearly three times as abundant over extended periods in the mouth of Head Harbour Passage, New Brunswick, as in that of the superficially similar entrance to Letite Passage about 10 km further north. They noted that there appeared to be no difference in abundance of herring of the right size range in the two areas. This difference in porpoise distribution was attributed to topographic differences in Head Harbour Passage and the Letite approaches. In the former channel, the incoming tidal flow encounters resistance from several large islands and shoals, resulting in stronger and more widespread upwelling than is generated by the gentler slopes of Letite Passage (Graham 1933). The mixing in Head Harbour Passage brings into the surface layers significant quantities of deep-water plankton which are fed on by herring (Battle et al. 1936). Herring are also carried into near-surface waters by topographic upwelling, since peak tidal currents in the area move faster (Forrester 1958) than juvenile herring are able to swim for prolonged periods (Boyar 1961; Jovellanos and Gaskin 1983), making herring in Head Harbour Passage much more accessible to feeding porpoises than those within Letite Passage.

Biology

Growth and Age

The Harbour Porpoise at physical maturity attains an average body weight of about 54 kg at a standard length of about 155 cm. Females are slightly larger than males at all ages. Both sexes reach maturity earlier in the western North Atlantic than in the North Sea. In the former it is attained between three and

four years of age (Gaskin and Blair 1977); and between five and six respectively for males and females in the North Sea (van Utrecht 1978). For further information, refer to Gaskin et al. (1984) and Read (1990b). The life span of the species is at least 13 years (Gaskin and Blair 1977) in eastern Canadian waters, and 11 years or more in Japanese (and presumably other North Pacific) waters (Gaskin, Yamamoto and Kawamura, 1991). In practice, it is unusual to find many animals, even in relatively large samples, more than eight years of age. This led Nielsen (1972) to suggest that formation of osteodentine prevented dentinal layers from being deposited normally after this period, and de Buffrenil (1982) to conclude, from studies of layering in mandibular bone, that the life span was probably in excess of twenty years, as might be expected from the total body weight. Recent studies however, using much larger sample sizes, indicate that de Buffrenil's technique over-estimates age by a factor of two (Watts and Gaskin 1989), and that animals over eight years of age are simply rather rare in modern-day Harbour Porpoise populations.

Yurick and Gaskin (1987) found that sexual dimorphism is present from birth in the Harbour Porpoise, with neonatal skull length greater in the female; this dimorphism persists throughout life. Growth curves and maximum body lengths for both sexes were presented by Gaskin et al. (1984). For further information consult Noldus and de Klerk (1984).

Reproductive Cycle

The exact timing of the reproductive cycle varies slightly from region to region (Gaskin et al. 1984). Mating in most regions occurs between July and August following the majority of births between May and July. In the Fundy region the peak of parturition occurs in May. The peak of conception is in June (Read 1990a). Six or seven weeks of pre-implantation pregnancy follows conception and foetuses are first macroscopically detectable in early August (Read 1990a). Growth in early pregnancy is linear and synchronous and the gestation period is about 10.6 months (Read (1990a), although periods as short as nine months have been suggested by earlier workers. Neonate growth is rapid and the total duration of lactation is probably about nine months (Read 1990a), but may begin to decrease after about five months (Gaskin et al. 1984; Yasui and Gaskin 1986) despite a bonding between mother and young that may persist for about 18 months before complete independence is achieved. There is no evidence to support the existence of the kind of extended lactation that occurs in other larger odontocetes such as the Pilot Whale (Sergeant 1962). Calves of *Phocoena phocoena* show independent behaviour by early autumn, and the first solid food is found in the stomachs when the animals attain a body length of about 104 cm (Smith and Gaskin 1974). Møhl-Hansen (1954) recorded finding food in the stomachs of juvenile animals which he estimated were young of the year of about five months of age.

The presence in the Harbour Porpoise of proportionately large testes, a long penis, females larger than males, and little apparent social structure (Gaskin 1982), suggests that sperm competition is part of the basic reproductive strategy in this species, as in some other cetaceans and other orders of mammals (Ralls 1976; Brownell and Ralls 1986).

Studies of seasonal testis volume, diameter of seminiferous tubules and the presence or absence of spermatogenesis provides strong evidence of a seasonal male sexual cycle (Gaskin et al. 1984), something not found in larger odontocetes (Best 1969). This may be related to sperm competition, but also to selection for efficiency and economy of tissue weight and function in what is, after all, the smallest cold water cetacean. The active testes are exceptionally large in this species; in the average sexually active adult male they may together weigh more than 2 to 3 kg, compared with a total body weight of about 50 kg (Gaskin et al. 1984).

Møhl-Hansen (1954) found a very high (84%) pregnancy rate in adult females taken in the Danish winter drive fisheries (n = 111); a sharp contrast to the much lower rate reported by Gaskin et al. (1984) from the Bay of Fundy. Recent information (Read 1990b) shows that in September to October the percentage of pregnancies rises dramatically in the Fundy females, suggesting that the previous data obtained was biased by the early sampling period (May to August). Read (1990b) concluded that in the early and mid-August samples from Fundy, the event was not advanced enough to be detected by the routine gross necropsy then used. Alternatively, a fraction of the pregnant females may move into the region only in early autumn. Most female porpoises probably give birth every year (Read 1990b). Postpartum pregnancies in the Fundy region exceed 62% in most years, according to a preliminary assessment of the new data, paralleling the findings of Møhl-Hansen for the Baltic population.

Species Movements

A pattern of migration is apparent in most populations of the Harbour Porpoise, but it generally has to be derived from data on relative presence and absence in different seasons in specific adjacent areas. Radio-telemetry (Gaskin et al. 1975; Read and Gaskin 1985) has to-date only provided information on short-term movements but enough to indicate that although some animals may demonstrate seasonal home-range behaviour, others may wander for tens of kilometers within a day or so, and may or may not return to the area of release.

Apparent movements of Harbour Porpoises in Newfoundland-Labrador were summarized by

Gaskin (1984). The species is common in the Trinity Bay region only from May to July. The relative timing of occurrence in the Gulf of St. Lawrence and the Bay of Fundy suggests that the Newfoundland population is distinct, and the supposition is that it goes further north in summer. Given the spring concentrations off eastern Newfoundland and Labrador, the late summer concentrations that occur off West Greenland in August-September, and the absence of summer sightings off eastern Newfoundland or on the northern Labrador-Baffin Island coasts, there seems a strong circumstantial case for considering Newfoundland-Labrador and West Greenland to be different seasonal zones of occupation of a single migratory population. This conclusion has been reinforced by Stenson and Reddin's (1990) discovery of animals out in the Labrador Sea. Summer ice distribution is probably a major limiting factor in occurrence on the western side of the Strait (M. C. Mercer, Department of Fisheries and Oceans, St. John's, Newfoundland, personal communication).

An eastward and offshore movement into the midstream and eastern region of the St. Lawrence during the late autumn and early winter months has not been fully documented, but must occur as the range in the western region becomes restricted by falling water temperatures and ice formation in some areas. There are no data on possible seasonal movements of Harbour Porpoises on the Atlantic coast of Nova Scotia, other than an unpublished report by G. A. Mertens that they can be seen off St. Ann's Bay region in May, moving towards the Gulf.

The Bay of Fundy-northern Gulf of Maine population, as indicated earlier, attains peak numbers in July-September. No large concentrations have been recorded further south along the coast of Maine in late fall or early winter. The CeTAP surveys (Winn 1982) revealed a dispersed population in this period, spread out from the northern Gulf of Maine, past Cape Cod to the vicinity of Long Island. Kraus (New England Aquarium, Boston, Massachusetts, personal communication) reported some moderate concentrations sighted during aerial surveys of Georges Bank in May. Banks such as this, with surface temperatures of 8 to 10°C along their southern and offshore margins, and possessing ample stocks of fish during all months of the year, may provide important wintering grounds for Harbour Porpoises. Almost all stranding records for the coastline from New York to North Carolina are from winter months. There are also a few stranding records from eastern Florida (A. J. Read, Department of Zoology, University of Guelph, Guelph, Ontario, personal communication). Similarly, the Harbour Porpoise can be regarded as primarily a late autumn-early spring component of the marine mammal fauna of the New Hampshire coast (S. Mercer, personal communication). It is rarely recorded there between June and early September. In the absence of results from tag returns, it cannot be shown conclusively that these are the seasonal movements of a single population, but the indirect and circumstantial evidence is reasonably compelling.

Limiting Factors

Cetaceans, with their single calf, and post-partum oestrus occurring in a significant number of individuals in some species, including the Harbour Porpoise, have little flexibility in their reproductive cycle to compensate effectively for additional mortality. The only density-dependent responses which seem feasible for this species in the presence of sufficient food are increases in juvenile growth rate and slight reduction in the age in sexual maturity. The number of young cannot feasibly increase (twins occur with a frequency of about 0.028 in some whale populations, but there is little direct evidence to suggest that both survive), and the length of the individual reproductive cycle cannot be shortened.

The Harbour Porpoise's general reliance on schooling fish of commercial importance as major prey items puts it in a position of direct competition with fishing industries in the regions where the densest concentrations of such species occur. Given the above constraints, over-exploitation of several prey species simultaneously could indirectly lead to a rapid decline in Harbour Porpoise reproductive and recruitment success.

Fortunately, directed hunts by coastal fishermen taking this species for meat and oil are now very limited, and many of the animals caught in eastern North American and European herring weirs and pound nets and Japanese coastal salmon traps are released alive. Mortalities from these sources are small.

It is evident that the Harbour Porpoise populations are in trouble in several parts of the northern hemisphere; it has virtually disappeared from much of the Baltic Sea (Andersen 1972; Kinze 1985a), the Black Sea (IWC 1982, 1983), and is very likely declining rapidly in the southern North Sea and the English Channel (Evans 1987; van Kreveld 1987). The primary factor in the case of the Black Sea decline was directed hunting by fishermen from the USSR and Turkey, in other areas the major culprit is almost certainly incidental catches by groundfish gill nets, although there was a large directed catch in Danish waters in the 1940s (Møhl-Hansen 1954). Entrapments in United Kingdom waters were reviewed by Northridge (1990), in Swedish waters by Lindsted (1990), and in Portugal by Sequeira (1990).

The salmon drift net fishery killed at least 1500 per annum in the early 1970s off West Greenland (Lear and Christensen 1975). Stenson and Reddin

(1990) reported catches in drift nets during experimental salmon tagging that ranged from 0.01 per nautical mile of net per hour off West Greenland in summer to 0.14 in the Newfoundland Basin in spring.

There are now data for the coast of Labrador; Lien (1983) initially recorded a few animals in fishing gear in the vicinity of Red Bay, and concluded that catches were likely to be significantly greater than the records indicate, largely because of a reluctance by fishermen to report incidental entrapments. After analyzing data from a survey made in 1982 using log books and interviews, it was evident that catches were indeed much larger; the known kill from 28 harbours (out of a total of 80) was 111 animals in 1982, but the annual average, excluding very large catches in the Square Islands area, was at least 160, and the total could in practice be much higher (Lien 1989). Lien (1983), and Pratt and Nettleship (1987) reported large catches in the southeastern part of Newfoundland, mostly from gill nets in the inshore cod fishery. In this region the catches are made almost entirely in June and July. Lien et al. (1987) tabulated 24 specimens taken in those months in 1987, all but one from groundfish gill nets; his survey results (Lien 1989) indicated that catches in this region are large, at least in the hundreds per year, and possibly in the low thousands.

Laurin (1976) reported that gill netters along the south shore of the St. Lawrence took an unspecified number each year. Recently an assessment of the magnitude of the problem in this region has been initiated by the Department of Fisheries and Oceans (Fontaine et al. 1990). In 1988 the minimum number reported was 623 Harbour Porpoises taken in fishing gear on the north and south shores of the St. Lawrence; Fontaine and his co-workers estimated that the real catch was probably at least twice this.

The history of gill net entrapments of Harbour Porpoises on the west coast from Alaska to Washington was summarized by Gaskin (1984). The serious threat posed by high levels of gill net catches from a demonstrably rather small population off the coast of central California has been provided by Hanan et al. (1986), Heyning et al. (1990) and Jefferson et al. (1990). Gearin et al. (1990) studied the impact of a Chinook Salmon (*Onchorhynchus tshawytscha*) set net fishery in the western Strait of Juan de Fuca and on the north coast of Washington State in 1988 and 1989; 102 kills were recorded in 1988 and 27 (with much less fishing effort) in 1989.

The gill net catches of Harbour Porpoises in New England coastal waters were summarized by Gaskin (1984); the extent and size of the catches in recent years has been discussed by Hoyt (1989). Read and Gaskin (1988) presented data on the catches from the Bay of Fundy gill net industry during the mid-1980s, while Kraus et al. (1990) and Payne et al. (1990) reported on those from the nearshore waters of the northeastern United States. The Bay of Fundy–Gulf of Maine area is the only region where sustained studies have been made. The conclusions drawn by Read and Gaskin (1988) and Read et al. (1990) are not reassuring. A whole series of symptoms of population numerical decline and changes in juvenile growth and the age at sexual maturity is evident (Read 1990b; Read and Gaskin 1990). The gill net catch of porpoises per boat declined from 5.5 in 1986 to 4.6 in 1987 to 3.8 by 1988. The catch per boat in the inshore (Campobello Island) region dropped even more drastically, from about 5.0 to 1.3 in 1988. The catch and total effort in each of these seasons has fluctuated, but the implication is strong that the inshore harbour porpoise population is being significantly reduced by the incidental catches. While surveyed densities in the offshore area north of Grand Manan have not changed, probably because of the contagious distribution always found on preferred feeding grounds, a decline in the coastal waters of Deer Island and in adjacent areas such as Back Bay and Letite, was documented by Gaskin and Watson (1985) as starting about 1974. Identification of a primary cause was confounded by a coincident drop in surface temperatures which suggested oceanographic changes might be involved.

Mean summer temperatures have risen again since 1978, but without a concurrent return of porpoises to the area. Survey effort off Deer Island has been much reduced in the last few years until 1990, but qualitatively replaced by local whale watching operations. T. Beatty (Sunbury Shores Nature Centre, St. Andrews, New Brunswick, personal communications) reported sighting only about eight animals during the whole 1988 season, and perhaps a dozen in 1986 and 1987. This decline was confirmed by R. Bosein (Captain, University of New Brunswick Research Vessel, Cummings Cove, Deer Island, West Isles, New Brunswick, personal communication). This inshore region was previously documented as being particularly frequented by mothers with new calves (Smith and Gaskin 1983). In the 1970s from 20 to 100 animals might be expected to be seen in a single day. Watson and Gaskin (1985) noted a number of recognizable individuals returning to the Fish Harbour region of Deer Island each year. The former habit of mainland gill netters of setting nets in a line across about a third of the approaches to Deer Island, with the nets across Head Harbour Passage covering perhaps another third, may well have been killing animals of this inshore "deme" faster than others were learning to utilize the area.

Further indications of changes in population structure are: (1) an increase in the mean length of calves at specific weeks in the season in comparison to earlier years, (2) a measurable decrease in the age at

sexual maturity, (3) the virtual disappearance of large (155 cm+) animals in the samples of the 1980s, and (4) the similar virtual absence of animals more than eight years of age (Read and Gaskin 1990). A greater proportion of the females now appear to be maturing at three years of age than in the study made by Gaskin and Blair (1977), although these data are still equivocal and require larger sample sizes. This may not be a classic density-dependent response, as might generally be supposed, but rather a reflection of a shrinking reproductive component of the population being composed of a high proportion of primiparous females.

The most parsimonious explanation for this evident decline is the impact of Fundy gill net kills (*c.* 100 per year on average), coupled with weir deaths (*c.* 15/year), on a population which is almost certainly the same as that which winters off southern New England (Gaskin 1984) where it is subjected to gill net kills estimated at 280 to 800 per annum (Polacheck 1989). Kraus et al. (1990) believed that the real value is nearer 1000 per year.

The dynamics of population growth in phocoenid porpoises was investigated by Barlow (1986), based largely on the reproductive parameters summarized by Gaskin et al. (1984) and re-evaluated by Woodley and Read (1991) using additional data from the Fundy region in the late 1980s. Based on the most realistic of three models of Harbour Porpoise population growth presented by Woodley and Read (1991), and given the restrictions of one young per year, a probable neonate natural mortality of about 0.41, and the relatively late maturity and short life span, the maximum rate of annual production could not possibly exceed 10%. Given that natural mortality will continue, it is doubtful if the real rate of replacement could exceed 4%. Woodley and Read (1991) contended that this species was unlikely to sustain even an annual incidental mortality of 5%. Natural mortality might even be increased by continued periodic massing of predators such as sharks [as was documented by Brodie and Beck (1983) in the case of Sable Island Grey Seals] to prey on specific seasonal aggregations of a population shrinking in absolute size. Given also that the best conservative estimate for the Fundy-northern Gulf of Maine population by Kraus et al. (1983) was 7956 ± 1327 and that the annual incidental kill is probably in excess of 600 animals per year, then the population is almost certainly in decline even if we accept the upper range limit for population size. At the lower range limit, which is closer to the 4000 estimated by Gaskin (1977), the decline will be much steeper.

The impact of organochlorine hydrocarbons on reproduction in cetaceans remains largely unknown, although Otterlind (1976) and Wolff (1981) have in part attributed reproductive disorders in these animals to high PCB concentrations in tissues. No gross disorders have been noted by the University of Guelph group during some 350 necropsies between 1969 to 1988, but the levels of organochlorine residues in the Fundy-Gulf of Maine population are documented as being some of the highest in the world (Gaskin 1985) and in 1976 these were on the rise again after declining in blubber of Harbour Porpoises between 1969 and 1973 (Gaskin et al. 1982). If organochlorines are responsible for reproductive disorders in small cetaceans, the Fundy-Gulf of Maine Harbour Porpoise population would be a prime candidate.

Trade and Exploitation

There is little evidence of past or present trade in *Phocoena phocoena* or its products, although Tressler (1923, *not seen*: referred to by Mitchell 1975) described the export of salted porpoise meat from northern Norway at that time. The species has not been found to be a suitable animal for seaquaria, although a few animals have been displayed in their countries of origin, e.g., Denmark and Japan. Possibly some meat has been traded at times between coastal Indian communities in Canada and the United States. Gilpin (1875) described a thriving Mic-Mac fishery for the Harbour Porpoise off the Fundy coast of Nova Scotia in the last century. This fishery is believed to have started in the late 18th century (Mitchell 1975). The Passamaquoddy Indians of northern Maine took a few animals each summer by shooting, at least into the 1980s. Animals taken fresh from gill nets may be eaten in some coastal communities in New Brunswick, Quebec, Newfoundland, and Labrador (Lien 1983; Gaskin 1984). It is also taken for food in Greenland (Kapel 1975) and in Iceland (Saemundsson 1939). Major drive fisheries used to exist in Denmark (Møhl-Hansen 1954) and it was also taken in directed fisheries in Poland (Ropelewski 1957). There are no data for past Bulgarian exploitation of Harbour Porpoise in the Black Sea, but Jelescu (1960) documented activities in coastal waters of Romania, and the impact of catches by the USSR and Turkey (IWC 1983, 1984) were referred to earlier in this review. Scheffer and Slipp (1948) and Mitchell (1975) reported catches of Harbour Porpoises by coastal Indian communities in the Pacific Northwest states.

Special Significance of the Species

The Harbour Porpoise is a well-known pelagic predator in the upper trophic level of the coastal food web in northern temperate latitudes. It has special significance because it is the smallest of the cold-water marine cetaceans, and therefore of particular scientific interest for studies on marginal bioenergetic economics and natural selection pressures. Beyond this, it has potential value as an indicator species; it is still generally regarded as a common animal, but is

actually one which is manifestly becoming much less common in several major portions of its range (IWC 1983; van Kreveld 1987). Such a clear warning signal cannot easily be ignored by government agencies responsible for coastal shelf management; it becomes obvious that some serious dysfunction is present in the system. In this case the decline is in large part the result of the virtually uncontrolled use of groundfish gillnets in many countries.

Because the Harbour Porpoise is near the top of the coastal food web and has a large fat store to function as a reserve and for thermo-regulatory purposes, it becomes a mobile storage vat for just about every kind of lipophilic organic chemical contaminant that finds its way into coastal waters. While there are many problems inherent in the accurate interpretation of such residues (Aguilar 1985), the general patterns of the stored compounds provide a reasonable toxicological overview of which compounds might merit particular attention. Furthermore, because the species has such a wide range in the northern hemisphere, it can be used for comparative studies across continental ranges, not just from one relatively local region to another. For example, while it is evident that organochlorine levels are lower in Newfoundland waters than in the Fundy region (Gaskin et al. 1982), they are also much lower in northern Japanese waters than in western North American or western European coastal regions.

Evaluation

The true population status of the Harbour Porpoise is unknown throughout most of the coastal waters of Canada. In all areas it has been subjected to incidental catches of unknown magnitude by gill nets. In the one area where the problem has been systematically examined over several years, Bay of Fundy-New England, the impact would seem to be serious. There is evidence of a change in population structure and some population decline in the inshore waters over about 15 years, which became much more evident in 1986 to 1988. Given the known limited reproductive flexibility of the species and the similarity of this developing pattern to that already recognized in European waters, it is strongly recommended that the status of the Harbour Porpoise along the Northwest Atlantic coast of Canada remain as threatened; there is however, insufficient scientific evidence to designate a status for the Canadian population in the Northeast Pacific, although I would suspect it is vulnerable.

Acknowledgments

A review of this kind cannot be made successfully without the assistance and cooperation of many. I would like to extend sincere thanks to those who gave advice, comments and in some cases, unpublished data: R. W. Baird of Victoria, British Columbia; P. Béland, Institute National d'ecotoxicologie du Saint Laurent, Rimouski, Québec; the late M. Bigg, Department of Fisheries and Oceans, Nanaimo, B.C.; D. Goodman, Fisheries Research Branch, Department of Fisheries and Oceans, Ottawa, Ontario; W. Hoek, Department of Fisheries and Oceans, Mont Joli, Québec; R. Reeves, of the Arctic Biological Station, Ste-Anne-de-Bellevue, Québec; Dr. J. Lien, Department of Psychology, Memorial University, St. John's, Newfoundland; D. Nagorsen, Royal British Columbia Museum, Victoria, B.C.; Ms. A. Morton, Echo Bay, Simmom Sound, B.C.; A. J. Read, Department of Zoology, University of Guelph, Guelph, Ontario; R. Sears, Mingan Islands Research Station, Sept-Iles, Québec; R. Bosein, Cummings Cove, Deer Island, New Brunswick; T. Beatty, Sunbury Shores, St. Andrews, N.B.; H. D. Fisher, formerly of the Department of Zoology, University of British Columbia, B.C.; I. McTaggart-Cowan, Victoria, B.C.; and G. A. Mertens, Lunenburg, Nova Scotia. Thanks are also extended to R. R. Campbell, Department of Fisheries and Oceans, Ottawa, Ontario; W. Hoek, J. Brazil of the Newfoundland Wildlife Division, St. John's, Newfoundland, J. Lien and two anonymous reviewers, whose constructive advice was most useful and appreciated during the development of the final version of the manuscript.

Funding in support of the production of the report was made possible through contributions from The Department of Fisheries and Oceans and World Wildlife Fund (Canada).

Literature Cited

Aguilar, A. 1985. Compartmentation and reliability of sampling procedures in organochlorine pollution surveys of cetaceans. Residue Reviews 95: 91–114.

Andersen, S. H. 1972. On the state of the stock of common porpoise in Danish waters. International Council for the Exploration of the Sea. Document 1972/N:6: 1–4.

Baird, R. W., K. M. Langelier, and **P. J. Stacey.** 1988. Stranded whale and dolphin program of B.C. — 1987 Report. British Columbia Veterinary Medicine Association Report. Wildlife Veterinary Report 1: 9–12.

Barlow, J. 1986. Factors affecting the recovery of *Phocoena sinus*, the Vaquita or Gulf of California harbor porpoise. National Marine Fisheries Service, South West Fisheries Center, La Jolla, California, Administrative Report LJ-86-37. 19 pages.

Barlow, J. 1987. An assessment of the status of harbour porpoise populations in central California. National Marine Fisheries Service, South West Fisheries Center, La Jolla, California, Administrative Report LJ-87-06. 35 pages.

Barlow, J. 1988. Harbor porpoise, *Phocoena phocoena*, abundance estimations for California, Oregon, and Washington: I. Ship surveys. Fishery Bulletin (U.S.) 86: 417–432.

Battle, H. I., A. G. Huntsman, A. M. Jeffers, G. W. Jeffers, W. H. Johnson, and **M. A. McNavin.**

1936. Fatness, digestion, and food of Passamaquoddy young herring. Journal of the Fisheries Research Board of Canada 2: 401–429.

Béland, P. 1988. Échouages des mammifères marins sur les côtes du Québec dans l'estuaire et le golfe du Saint-Laurent en 1987. Rapport d'Institut national d'Ecotoxicologie du Saint-Laurent, Rimouski, Québec. 40 pages.

Béland, P., D. Martineau, P. Robichaud, R. Plante, et **R. Greendale.** 1987. Echouage de mammifères marins sur les côtes du Québec dans l'estuaire et le golfe du Saint-Laurent de 1982 à 1985. Rapport technique canadien sciences des halieutiques et aquatiques 1506. Iv+44 pages.

Best, P. B. 1969. The sperm whale (*Physeter catodon*) off the west coast of South Africa. 3. Reproduction in the male. Investigational Reports of the Division of Sea Fisheries of South Africa 72: 1–20.

Boyar, H. C. 1961. Swimming speed of immature Atlantic herring with reference to the Passamaquoddy tidal project. Transactions of the American Fisheries Society 90: 21–26.

Brawn, V. M. 1960. Seasonal and diurnal vertical distribution of herring (*Clupea harengus* L.) in Passamaquoddy Bay, N.B. Journal of the Fisheries Research Board of Canada 17: 699-711.

Brodie, P., and **B. Beck** 1983. Predation by sharks on the grey seal (*Halichoerus grypus*) in eastern Canada. Canadian Journal of Fisheries and Aquatic Sciences 40: 267–271.

Broekema, J. W., and **C. Smeenk** 1987. The European Cetacean Society Report of the 1987 Meeting, Hirtshals, Denmark. European Cetacean Society Newsletter 1: 1–77.

Brownell, R. L., Jr., and **K. Ralls.** 1986. Potential for sperm competition in baleen whales. Report of the International Whaling Commission, Special Issue Number 8: 97–112.

Calambokidis, J. 1986. Chlorinated hydrocarbons in harbor porpoise from Washington, Oregon and California: Regional differences in pollutant ratios. National Marine Fisheries Service, Southwest Fisheries Center, Administrative Report LJ-86-35C. 29 pages.

de Buffrenil, F. 1982. Données préliminaires sur la presence de lignes d'arret de croissance peroistiques dans la mandibule du Marsouin commun, *Phocoena phocoena* (L.), et leur utilisation comme indicateur de l'âge. Canadian Journal of Zoology 60: 2557–2567.

Diamond, S. L., and **D. A. Hanan.** 1986. An estimate of harbor porpoise mortality in California set net fisheries April 1, 1983 through March 31, 1984. National Marine Fisheries Service, Southwest Region, Terminal Island, California, Administrative Report SWR-86-15. 40 pages.

Evans, P. G. H. 1987. The natural history of whales and dolphins. Facts on File Publications, New York and Oxford. 343 pages.

Fiscus, C. H., and **K. Niggol.** 1965. Observations of cetaceans off California, Oregon and Washington. Special Scientific Report of the United States Fish and Wildlife Service — Fisheries Report Number 389: 1–27.

Fisher, H. D., and **R. J. Harrison.** 1970. Reproduction in the common porpoise (*Phocoena phocoena*) of the North Atlantic. Journal of Zoology, London 161: 471–486.

Flaherty, C., and **S. Stark.** 1982. Harbor porpoise (*Phocoena phocoena*) assessment in "Washington Sound". Final Report for Subcontract 80-ABA-354, NOAA, NMFS, National Marine Mammal Laboratory, Seattle, Washington. 84 pages.

Fontaine, P.-M., M. O. Hamill, and **M. C. S. Kingsley.** 1990. [*Abstract*]. Incidental catches of harbour porpoise (*Phocoena phocoena*) in the Gulf of St. Lawrence and the St. Lawrence River Estuary, Quebec, Canada. International Whaling Commission Symposium on mortality of cetaceans in passive fishing nets and traps. La Jolla, California, October 20-21, 1990: 10.

Forrester, W. D. 1958. Current measurements in Passamaquoddy Bay and the Bay of Fundy 1957-1958. Department of Mines and Technical Surveys, Ottawa, Ontario. Tidal Publication Number 40.

Gaskin, D. E. 1977. Harbour porpoise, *Phocoena phocoena* (L.) in the western approaches to the Bay of Fundy 1969-75. Report of the International Whaling Commission 27: 487–492.

Gaskin, D. E. 1984. The Harbour Porpoise *Phocoena phocoena* (L.): Regional populations, status and information on direct and indirect catches. Report of the International Whaling Commission 34: 569–586.

Gaskin, D. E. 1985. The ecology of whales and dolphins. Heinemann, London and Exeter, New Hampshire. 459 pages.

Gaskin, D. E., and **B. A. Blair.** 1977. Age determination of harbour porpoise, *Phocoena phocoena* (L.), in the western North Atlantic. Canadian Journal of Zoology 55: 18–30.

Gaskin, D. E., and **A. P. Watson** 1985. The Harbour Porpoise, *Phocoena phocoena*, in Fish Harbour, New Brunswick, Canada: Occupancy, distribution and movements. Fishery Bulletin (U.S.) 83: 427–442.

Gaskin, D. E., P. W. Arnold, and **B. A. Blair.** 1974. *Phocoena phocoena*. Mammalian Species 42: 1–8.

Gaskin, D. E., M. Holdrinet, and **R. Frank.** 1982. DDT residues in blubber of harbour porpoise, *Phocoena phocoena* (L.) from eastern Canadian waters during the five-year period 1969-1973. Pages 135-143 *in* Mammals in the Seas. FAO Fisheries Series Number 5, Volume IV, Rome, Italy.

Gaskin, D. E., A. J. Read, G. J. D. Smith, and **P. F. Watts.** 1985. Population dispersal, size and interactions of Harbour Porpoises in the Bay of Fundy and Gulf of Maine. Canadian Technical Reports in Fisheries and Aquatic Sciences 291: 1–28.

Gaskin, D. E., G. J. D. Smith, and **A. P. Watson.** 1975. Preliminary study of movements of Harbour Porpoises (*Phocoena phocoena*) in the Bay of Fundy using radiotelemetry. Canadian Journal of Zoology 53: 1466–1471.

Gaskin, D. E., G. J. D. Smith, A. P. Watson, W. Y. Yasui, and **D. Yurick.** 1984. Reproduction in the porpoises (Phocoenidae): Implications for management. Report of the International Whaling Commission, Special Issue 6: 135–148.

Gearin, P. J., S. S. Melion, R. L. DeLong, and **H. Kajimura.** 1990. [*Abstract*]. Harbor porpoise interactions with the Makah Chinook salmon set net fishery in Washington State. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 11.

Goodson, A. D., and **M. Klinowska.** 1990. [*Abstract*]. Enhancing the acoustic detectability of fishing nets. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 14.

Graham, M. 1933. Investigations of the herring of Passamaquoddy and adjacent regions. Journal of the Fisheries Research Board of Canada 2: 95–127.

Hall, J. D. 1979. A survey of cetaceans of Prince William Sound and adjacent waters — their numbers and seasonal movements. Final Report for National Oceanic and Atmospheric Administration, on contract 01-6-022-1560.

Hanan, D. A., S. L. Diamond, and **J. P. Scholl.** 1986. An estimate of Harbor porpoise mortality in California set net fisheries April 1, 1984 through March 31, 1986. National Marine Fisheries Service, Southwest Region, Terminal Island, California. Administrative Report SWR-86-16. 38 pages.

Hayase, S., Y. Watanabe, and **T. Hatanaka.** 1990. [*Abstract*]. Preliminary report on the Japanese fishing experiments using subsurface gillnets in the south and North Pacific, 1989-1990. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 18.

Heyning, J. E., T. D. Lewis, and **C. D. Woodhouse.** 1990. [*Abstract*]. Mortalities of odontocetes from gear off southern California. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 19.

Hoyt, E. 1989. New England's harried harbor porpoise. Defenders 64(1): 10–17.

Iles, T. D. 1979. The ecology of the herring fisheries of the Bay of Fundy. Pages 27-52 *in* Evaluation of recent data relative to potential oil spills in the Passamaquoddy area. *Edited by* D. J. Scarratt. Fisheries and Marine Service Technical Report 901. 107 pages.

IWC 1982. Report of the Sub-committee on Small Cetaceans. (Annex H). Report of the International Whaling Commission 32: 113–126.

IWC. 1983. Report of the Sub-committee on Small Cetaceans. (Annex H). Report of the International Whaling Commission 33: 152–167.

IWC. 1984. Report of the Sub-committee on Small Cetaceans. (Annex H). Report of the International Whaling Commission 34: 144–160.

IWC. 1990. [*Abstracts*]. Symposium on mortality of cetaceans in passive fishing nets and traps. La Jolla, California, October 20-21, 1990.

Jefferson, T. A., B. E. Curry, and **N. A. Black.** 1990. [*Abstract*]. Harbor porpoise mortality in the Monterey Bay halibut gillnet fishery, 1989. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 20.

Jelescu, N. 1960. La pêche industrielle aux dauphins dans la mer noire-littoral romanian. Buletinul de Cerceteri Pisicole (Romania) 19: 64–70.

Jovellanos, D. L., and **D. E. Gaskin.** 1983. Predicting the movements of juvenile Atlantic herring (*Clupea harengus harengus*) in the S.W. Bay of Fundy using computer simulation techniques. Canadian Journal of Fisheries and Aquatic Sciences 40: 139–146.

Kanwisher, J., and **G. Sundnes.** 1965. Physiology of a small cetacean. Hvalradets Skrifter 48: 45–63.

Kapel, F. O. 1975. Preliminary notes on the occurrence and exploitation of smaller Cetacea in Greenland. Journal of the Fisheries Research Board of Canada 32: 1079–1082.

Kapel, F. O. 1977. Catch of belugas, narwhals and Harbour Porpoises in Greenland, 1954-1975, by year, month and region. Report of the International Whaling Commission 27: 507–520.

Kinze, C. C. 1985a. Intraspecific variation in Baltic and North Sea harbour porpoises (*Phocoena phocoena* L.) (1758). Videnskabelige Meddelesler fra Dansk naturhistorik Forening i Kjøbenhavn 146: 63–74.

Kinze, C. C. 1985b. Et ars observationer af Marsvin (*Phocoena phocoena*) fra danski faergeruter. Flora og Fauna 91: 21–27.

Klinowska, M., and **A. D. Goodson.** 1990. [*Abstract*]. Some non-acoustic approaches to the prevention of entanglement. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 21.

Kraus, S. D., and **J. H. Prescott.** 1981. Distribution, abundance and notes on the large cetaceans of the Bay of Fundy, summer and fall 1980. Final Report to U.S. Department of Commerce, National Marine Fisheries Service, on contract NA-80-FA-2-00048. 66 pages.

Kraus, S. D., C. Coogan, and **P. M. Fiorelli.** 1990. [*Abstract*]. Incidental take of cetaceans by fishing activities in the nearshore waters of the northeastern U.S., 1975-1989. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 22.

Kraus, S. D., J. H. Prescott, and **G. S. Stone.** 1983. Harbour porpoise, *Phocoena phocoena*, in the U.S. coastal waters of the Gulf of Maine: A survey to determine seasonal distribution and abundance. Report to the Director, National Marine Fisheries Service, Northeast Region, Woods Hole, Maryland. 15 pages.

Lansdown, R. V. 1988. [*Manuscript*]. Seasonal occurrence of the Harbour Porpoise *Phocoena phocoena* L. in Roaringwater Bay, County Cork, Ireland. 10 pages.

Laurin, J. 1976. Preliminary study of the distribution, hunting and incidental catch of harbour porpoise, *Phocoena phocoena* L. in the Gulf and estuary of the St. Lawrence. ACMRR/MM/SC/93, FAO Scientific Consultation on Marine Mammals, Bergen.

Lear, W. H., and **O. Christensen.** 1975. By-catches of harbour porpoise (*Phocoena phocoena*) in salmon driftnets at West Greenland in 1972. Canadian Journal of Zoology 32: 1223–1228.

Leatherwood, S., *Editor*. 1983. Marine mammals of the eastern Bering Sea and Shelikof Strait, Alaska. Results of aerial surveys March 1982-1983. Contract Report NA-82-RAC-00039 to US Department of Interior, Minerals Management Service, Juneau, Alaska.

Lien, J. 1983. [*Manuscript*]. Incidental catch of harbour porpoise (*Phocoena phocoena*) off Newfoundland and Labrador. Memorial University, St. John's, Newfoundland. 2 pages.

Lien, J. 1989. Incidental catch of harbour porpoise (*Phocoena phocoena*) in waters off Newfoundland and Labrador: Some estimates based on present data and a request for further study. Report to the Workshop on Harbour Porpoise, St. Andrews Biological Station, Department of Fisheries and Oceans, St. Andrews, New Brunswick, 22 August 1989. 8 pages.

Lien, J., J. Papineau, and **L. Dugan.** 1987. Incidental entrapments of cetaceans, sharks and marine turtles in inshore fishing gear reported during 1987 in Newfoundland and Labrador. A Preliminary Report to the Department of Fisheries and Oceans and the Newfoundland and Labrador Department of Fisheries. Department of Fisheries and Oceans, St. John's Newfoundland. 36 pages.

Lindsted, I. 1990. [*Abstract*]. Mortality of harbour porpoises in the Swedish gill net fishery. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, 20-21 October 1990: 24.

Matkin, C. O., and **F. H. Fay.** 1980. Marine mammal-fishery interactions in the Copper River and in Prince William Sound, Alaska, 1978. U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia PB 80-15936.

Mercer, M. C. 1973. Observations on distribution and intraspecific variation in pigmentation patterns of odontocete Cetacea in the western North Atlantic. Journal of the Fisheries Research Board of Canada 30: 1111–1130.

Mitchell, E. 1975. Porpoise, dolphin and small whale fisheries of the world — status and problems. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland. 129 pages.

Møhl-Hansen, U. 1954. Investigations on reproduction and growth of the porpoise (*Phocoena phocoena*) (L.)) from the Baltic. Videnskabelige Meddelesler frd Dansk naturhistorik Forening 116: 369–396.

Murison, L. D., and **D. E. Gaskin.** 1989. The distribution of right whales and zooplankton in the Bay of Fundy. Canadian Journal of Zoology 67:1411–1420.

Nielsen, H. G. 1972. Age determination of the harbour porpoise *Phocoena phocoena* (L.) (Cetacea). Videnskabelige Meddelesler fra Dansk naturhistorik Forening 135: 61–84.

Noldus, L. P. J. J., and **R. J. J. de Klerk.** 1984. Growth of the skull of the harbour porpoise, *Phocoena phocoena* (Linnaeus, 1758), in the North Sea, after age determination based on dentinal growth layer groups. Zoologische Mededelingen Leiden 58: 213–239.

Northridge, S. P. 1990. [*Abstract*]. Accidental capture of marine mammals by fisheries in British waters with particular emphasis on gill net fisheries. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 32.

Otterlind, G. 1976. The harbour porpoise (*Phocoena phocoena*) endangered in Swedish waters. International Council for Exploration of the Sea, Document C. M. 1976/N: 16.

Payne, P. M., G. Power, and **C. T. Yustin.** 1990. Interactions between the New England sink-gillnet fishery and the harbor porpoise, *Phocoena phocoena*. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990: 34.

Piatt, J. F., and **D. N. Nettleship.** 1987. Incidental catch of marine birds and mammals in fishing nets off Newfoundland, Canada. Marine Pollution Bulletin 18: 344-349.

Pike, G. C., and **I. B. MacAskie.** 1969. Marine mammals of British Columbia. Bulletin of the Fisheries Research Board of Canada Number 171: i-x + 1–54.

Pingree, R. D., G. R. Forster, and **G. K. Morrison.** 1974. Turbulent convergent tidal fronts. Journal of the Marine Biological Association of the United Kingdom 54: 469–479.

Polacheck, T. 1989. Harbour porpoises and the gillnet fishery. Oceanus 32: 63–70.

Prescott, J. H., and **P. M. Fiorelli.** 1980. Review of the harbour porpoise (*Phocoena phocoena*) in the U.S. Northwest Atlantic. National Technical Information Service, U.S. Department of Commerce PB-80-176928. 64 pages.

Prescott, J. H., S. D. Kraus, D. E. Gaskin, G. J. D. Smith, and **M. Brander.** 1981. Harbour porpoise (*Phocoena phocoena*). Distribution, abundance, survey methodology and preliminary notes on habitat use and threats. Final Report to U.S. Department of Commerce, National Marine Fisheries Service, Contract NA-80-FA-00009. 61 pages.

Ralls, K. 1976. Mammals in which females are larger than males. Quarterly Review of Biology 51: 245–276.

Read, A. J. 1990a. Reproductive seasonality in harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Canadian Journal of Zoology 68: 284–288.

Read, A. J. 1990b. Age at sexual maturity and pregnancy rates of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 47: 561–565.

Read, A. J., and **D. E. Gaskin.** 1985. Radio tracking the movements and activities of Harbour Porpoises *Phocoena phocoena* (L.) in the Bay of Fundy, Canada. Fishery Bulletin 83: 543–552.

Read, A. J., and **D. E. Gaskin.** 1988. Incidental catch of Harbour Porpoises in Bay of Fundy groundfish gill nets. Journal of Wildlife Management 52(3): 517–523.

Read, A. J., and **D. E. Gaskin.** 1990. Changes in growth and reproduction of harbour porpoises, *Phocoena phocoena*, from the Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 47: 2158–2163.

Read, A. J., L. Murison, P. Berggren, T. Woodley, A. Westgate, and **D. E. Gaskin.** 1990. [*Abstract*]. A tangled web: harbour porpoises and gill nets in the Bay of Fundy. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, 20-21 October 1990: 40.

Recchia, C. A., and **A. J. Read.** 1989. Stomach contents of harbour porpoises, *Phocoena phocoena* (L.), from the Bay of Fundy. Canadian Journal of Zoology 67: 2140–2146.

Ropelewski, A. 1957. Morswin (*Phocoena phocoena* L.) jako przylów w polskim rybolówstwie baltyckim. Prac Morsk Instyt Ryback 9: 427–437.

Saemundsson, B. 1939. Mammalia. Zoology of Iceland. Volume 4: 1-38. Eniar Munkgaard, Copenhagen and Reykjavik.

Scheffer, V. B., and **J. W. Slipp.** 1948. The whales and dolphins of Washington State with a key to the cetaceans of the west coast of North America. American Midland Naturalist 39: 257–337.

Schulze, G. 1987. Die Schweinswale. Die Neue Brehm-Bucherei, A. Ziemsen Verlag, Wittenberg Lutherstadt. 167 pages.

Sequeira, M. L. 1990. [*Abstract*]. Gillnets and cetacean mortality in Portugal. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, 20-21 October 1990: 42.

Sergeant, D. E. 1962. The biology of the pilot or pothead whale *Globicephala melaena* (Traill) in Newfoundland waters. Bulletin of the Fisheries Research Board of Canada Number 132: 1–84.

Sergeant, D. E. 1978. Ecological isolation in some Cetacea. Pages 20-33 *in* Contributions to the symposium on marine mammals, International Thereological Conference, Moscow. Academy of Sciences of the U.S.S.R. A. M. Severtsov, Institute of Evolutionary Morphology and Ecology of Animals. Moscow.

Silber, G. K., K. A. Waples, and **P. A. Nelson.** 1990. [*Abstract*]. Harbor porpoise behavioral responses to potential gillnet modifications. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, 20-21 October 1990: 44.

Smith, G. J. D., and **D. E. Gaskin.** 1974. The diet of harbour porpoises (*Phocoena phocoena* (L.)) in coastal waters of Eastern Canada, with special reference to the Bay of Fundy. Canadian Journal of Zoology 52: 777–782.

Smith, G. J. D., and **D. E. Gaskin.** 1983. An environmental index for habitat utilization by female harbour porpoises with calves near Deer Island, Bay of Fundy. Ophelia 22: 1–13.

Smith, G. J. D., A. J. Read, and **D. E. Gaskin.** 1983. Incidental catch of harbour porpoises, *Phocoena phocoena* L., in herring weirs in Charlotte County, New Brunswick. Fishery Bulletin of the U.S. National Marine Fisheries Service Number 81: 660–662.

Stenson, G. B., and **D. G. Reddin.** 1990. [*Abstract*]. Incidental catches of small cetaceans in drift nets during salmon tagging experiments in the Northwest Atlantic. International Whaling Commission Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, 20-21 October 1990: 46.

Taylor, G. L., and **P. K. Dawson.** 1984. Seasonal changes in density and behavior of harbor porpoise (*Phocoena phocoena*) affecting censusing methodology in Glacier Bay National Park, Alaska. Report of the International Whaling Commission 34: 479–483.

Tomilin, A. G. 1957. Mammals of the U.S.S.R. and adjacent Countries. Volume IX Cetacea. Izkatel'stvo Akademi Nauk U.S.S.R., Moscow. [Translated into English by the Israel Program for Scientific Translations and published in 1967 in agreement with the Smithsonian Institution and the National Science Foundation, Washington, D.C., U.S.A. 717 pages.]

U.S. Hydrographic Office. 1958. Oceanographic Atlas of the Seas, Part II. Arctic. Department of the Navy Hydrographic Office, Washington, D.C. 139 pages.

van Bree, P. J. H., D. E. Sergeant, and **W. Hoek.** 1977. A harbour porpoise, *Phocoena phocoena* (Linnaeus, 1758), from the MacKenzie River delta, Northwest Territories, Canada (Notes on Cetacea Delphinoidea VIII). Beaufortia 333: 99–105.

van Kreveld, A. 1987. The Harbour Porpoise in the North Sea and adjacent waters. Reasons for concern (a review). Report for Greenpeace, Damrak 83-I, 1012 LN Amsterdam, Netherlands. 55 pages.

van Utrecht, W. L. 1978. Age and growth in *Phocoena phocoena* Linnaeus, 1748 (Cetacea, odontoceti) from the North Sea. Bijdragen tot de Dierkunde 48: 16–28.

Watson, A. P., and **D. E. Gaskin.** 1983. Observations on the ventilation cycle of the harbour porpoise *Phocoena phocoena* (L.). Canadian Journal of Zoology 61: 126–132.

Watts, P., and **D. E. Gaskin.** 1985. Habitat index analysis of the harbour porpoise (*Phocoena phocoena*) in the southern coastal Bay of Fundy, Canada. Journal of Mammalogy 66(4): 733–744.

Watts, P., and **D. E. Gaskin.** 1989. A comparison of age determination techniques for the harbour porpoise, *Phocoena phocoena* (L.). Canadian Journal of Zoology 67: 1832–1836.

Winn, H. E. 1982. A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. outer continental shelf. Final Report of the Cetacean and Turtle Assessment Program. United States Department of the Interior, Bureau of Land Management, Washington, D.C. 437 pages.

Wolff, W. J. 1981. The status of marine mammals in the Wadden sea area. Pages 7-14 *in* Marine mammals of the Wadden Sea. *Edited by* P. J. H. Reijnders and W. J. Wolff. Final report of the section 'Marine Mammals' of the Wadden Sea Working Group Report 7.

Woodley, T. H., and **A. J. Read.** 1991. Potential rate of increase of a harbour porpoise (*Phocoena phocoena*) population subjected to incidental mortality in commercial fisheries. Canadian Journal of Fisheries and Aquatic Sciences 68: 2429–2435.

Worthy, G. A. J., S. Innes, B. M. Braune, and **R. E. A. Stewart.** 1987. Rapid acclimation of cetaceans to an open-system respirometer. Pages 115-126 *in* Approaches to marine mammal energetics. *Edited by* A. C. Huntley, D. P. Costa, G. A. J. Worthy, and M. A. Castellini. Society for Marine Mammalogy, Special Publication Number 1.

Yasui, W. Y., and **D. E. Gaskin.** 1986. Energy budget of a small cetacean, the harbour porpoise, *Phocoena phocoena* (L.). Ophelia 25: 183–197.

Yurick, D. B. 1977. Populations, subpopulations, and zoogeography of the Harbour Porpoise, *Phocoena phocoena* (L.). M.Sc. dissertation, Department of Zoology, University of Guelph, Guelph, Ontario. 148 pages.

Yurick, D. B., and **D. E. Gaskin.** 1987. Morphometric and meristic comparisons of skulls of the Harbour porpoise *Phocoena phocoena* (L.) from the North Atlantic and North Pacific. Ophelia 27: 53–75.

Yurick, D. B., and **D. E. Gaskin.** 1988. Asymmetry in the skull of the harbour porpoise *Phocoena phocoena* (L.) and its relationship to sound production and echolocation. Canadian Journal of Zoology 66: 399–402.

Accepted 31 May 1991

Supplemental Literature

By its very nature the COSEWIC assessment process is somewhat slow, as a result some aspects of species accounts may be out of date by the time they are published. The Harbour Porpoise is a case in point. In the last three years there has been a surge of interest in this species throughout its range, especially with respect to incidental captures in fishing gear. The abstracts of the 1990 Conference on cetacean mortalities in trap and gillnet fisheries were published in time to be incorporated into the body of this manuscript, but a significant number of informative articles published more recently are referenced in

this supplementary section to increase the number of sources available to the reader:

Björge, A., R. L. Brownell Jr., W. F. Perrin and **G. P. Donovan.** 1991. Significant direct and indirect catches of small cetaceans. A Report by the Scientific Committee of the International Whaling Commission. Cambridge, July 1991. 87 pages.

Annual Meeting of the Scientific Committee of the International Whaling Commission, San Diego, California, 20 May-12 June 1989.

Polacheck, T., and **L. Thorpe.** 1990 (1989). The swimming direction of harbor porpoise in relationship to a survey vessel. [Document SC/41/SM 25. 8 pp.]. Report of the International Whaling Commission 40: 463–470.

Annual Meeting of the Scientific Committee of the International Whaling Commission, Noordwijkerhout. The Netherlands, 10-23 June 1990.

Aguilar, A., and **A. Borrell.** 1990. Pollution and harbour porpoises in the eastern North Atlantic: a review. Document SC/42/SM25.

Andersen, L. W. 1990. The population structure of *Phocoena phocoena* in Danish waters. Document SC/42/SM50.

Barlow, J., and **D. A. Hanan.** 1990. An assessment of the status of harbor porpoise populations in California. Document SC/42/SM6.

Berggren, P., and **F. Pettersson.** 1990. Sightings of harbour porpoises (*Phocoena phocoena*) in Swedish waters. Document SC/42/SM30.

Björge, A., A. A. Hohn, C. Lockyer, and **T. Schwerder.** 1990. Summary report from the harbour porpoise age determination workshop, Oslo, 21-23 May 1990. Document SC/42/SM1.

Björge, A., and **S. Kaarstad.** 1990. Preliminary analysis of growth and reproduction of harbour porpoises *Phocoena phocoena* in Norwegian waters. Document SC/42/SM2.

Björge, A., and **N. Oien.** 1990. Distribution and abundance of harbour porpoise *Phocoena phocoena* in Norwegian waters. Document SC/42/SM3.

Celikkale, M. S. 1990. The fishery in the Black Sea. Document SC/42/SM40.

Evans, P. G. H. 1990. Harbour porpoises (*Phocoena phocoena*) in British and Irish waters. Document SC/42/SM49.

Hohn, A. A., and **R. L. Brownell, Jr.** 1990. Harbour porpoise in central California waters: Life history and incidental catches. Document SC/42/SM47.

Hohn, A. A., and **K. Peltier.** 1990. An annotated bibliography of harbour porpoise, *Phocoena phocoena*, life history and exploitation. Document SC/42/SM19.

Joiris, C. R., J. M. Bouquegneau, M. Bossicart, and **L. Holsbeek.** 1990. Mercury contamination of the harbour porpoise. *Phocoena phocoena* and other cetaceans from the North Sea and the Kattegat. Document SC4/2/SM15.

Kinze, C. 1990. Life table calculations of a theoretical harbour porpoise (*Phocoena phocoena*) population: predictions on longevity. Document SC/42/SM33.

Kremer, H., and **G. Schulze.** 1990. A review of cetaceans in German waters. Document SC/42/SM26.

Miyashita, T., and **N. V. Doroshenko.** 1990. Report on the whale sightings survey in the Okhotsk Sea August 1989. Document SC/42/O18.

Polacheck, T. 1990. Results of field tests of line transect methods for shipboard sightings survey for harbour porpoise. Document SC/42/SM38.

Polacheck, T., and **F. W. Wenzel.** 1990. What do stranding data say about harbour porpoise (*Phocoena phocoena*)? Document SC/42/SM39.

Smeenk, C., and **M. J. Addink.** 1990. The harbour porpoise in Dutch waters: evidence from stranding records. Document SC/42/SM27.

Stacey, P. J., R. W. Baird, and **D. A. Duffus.** 1990. A preliminary evaluation of incidental mortality of small cetaceans, primarily Dall's porpoise (*Phocoenoides dalli*), harbour porpoise (*Phocoena phocoena*), and Pacific white-sided dolphins (*Lagenorhynchus obliquidens*), in inshore fisheries in British Columbia, Canada. Document SC/42/SM20.

Annual Meeting of the Scientific Committee of the International Whaling Commission. Reykjavik, Iceland. May 1991.

Baird, R. W., and **T. J. Guenther.** 1991. Harbour porpoises *Phocoena phocoena* on the B.C. coast: A preliminary examination from stranded and incidentally caught animals. Document SC/43/SM03.

Miyashita, T., and **A. A. Berzin.** 1991. Report of the whale sighting survey in the Okhotsk Sea and adjacent waters in 1990. Document SC/43/05.

Ninth Biennial Conference on the Biology of Marine Mammals, Chicago, Illinois, 5-9 December 1991.

Berggren, P. 1991. Have incidental catches affected harbour porpoise (*Phocoena phocoena*) abundance in the Bay of Fundy? Abstracts: 6.

Dalheim, M., A. York, J. Waite and **C. Goebel-Diaz.** 1991. Alaskan harbor porpoise (*Phocoena phocoena*) population studies. Abstracts: 16.

Forney, K. A., and **J. Barlow.** 1991. Detecting trends in abundance of harbor porpoise, *Phocoena phocoena*, in central California. Abstracts: 2.

Fontaine, P. M., C. Barrette and **M. O. Hamill.** 1991. Testis size and reproduction of male harbour porpoise in the Estuary and the Gulf of St.-Lawrence, Quebec, Canada. Abstracts: 23.

Gaskin, D. E., S. Yamamoto, and **A. Kawamura.** 1991. Harbour porpoise *Phocoena phocoena* in coastal waters of Japan. Abstracts: 26.

Gearlin, P. J., and **M. A. Johnson.** 1991. Harbor porpoise food habits in Washington State. Abstracts: 26.

Hoek, W. 1991. An unusual aggregation of harbour porpoises (*Phocoena phocoena*) in the Gulf of St. Lawrence, Canada. Abstracts: 33.

Thomas, A., and **B. E. Curry.** 1991. A review of interactions between porpoises and gillnets. Abstracts: 36.

Lick, R. R. 1991. Crustaceans, fish and marine mammals as intermediate and final hosts of anisakine nematodes in German coastal waters. Abstracts: 43.

Long, D. L. 1991. A review of shark predation of cetaceans. Abstracts: 43.

Palka, D. L., and **T. D. Smith.** 1991. Line transect surveys used to describe ship avoidance of harbor porpoise in the Gulf of Maine. Abstracts: 52.

Rosel, P. E., and **M. G. Hayggod.** 1991. Relative discreteness of harbor porpoise stocks in the northeast Pacific from mDNA sequences. Abstracts: 59.

Sørensen, T. B. 1991. Reproductive seasonality in harbour porpoises, *Phocoena phocoena*, from Danish waters. Abstracts: 66.

Taylor, B. L. and **T. Gerrodette.** 1991. Uses of statistical power in conservation biology: detecting trends in abundance for the Vaquita. Abstracts: 67.

Wang, J. Y., D. E. Gaskin and **B. N. White.** 1991. Visible band variation in the DNA of harbour porpoise (*Phocoena phocoena* (L.)) from the Bay of Fundy. Abstracts: 71.

Wenzel, F. W. 1991. Cetacean strandings in Massachusetts (1900-1988), with emphasis on the harbor porpoise. Abstracts: 73.

Received 12 December 1991

Status of the Common Dolphin, *Delphinus delphis*, in Canada*

DAVID E. GASKIN

Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1

Gaskin, David. E. 1992. Status of the Common Dolphin, *Delphinus delphis*, in Canada. Canadian Field-Naturalist 106(1): 55–63.

The Common Dolphin, *Delphinus delphis*, is widely distributed in continental shelf regions throughout the world, especially in warm-temperate and subtropical latitudes. It penetrates the tropical zone in areas where relatively cool waters keep surface temperatures between about 15 to 26°C. It also moves seasonally into higher latitude temperate regions when relatively warm summer waters allow it to extend its range polewards. It feeds on pelagic schooling prey such as various species of squid, smelt, herring, mackerel, mullet and lantern fish. Maximum body lengths can range up to 260 cm in males and 246 cm in females, but most adults are smaller than this. It attains sexual maturity at about five to seven years of age, has a gestation period of 10 to 11 months, a lactation period of up to 10 months, a calving interval which is probably about two years, and calves which are 75 to 90 cm in length at birth. The maximum life span is not known. It is relatively heavily exploited in the Yellowfin Tuna (*Thunnus albacares*) industry of the eastern tropical Pacific, and was extensively hunted in the Black Sea for many years. In the coastal waters of North America it appears to be quite abundant, and not subject to any particular threat; it may feed in zones where groundfish gill nets and drift nets are not usually set in any numbers at present. It can be abundant off the coast of Nova Scotia and Newfoundland for a month or two in summer; this is almost certainly the same population which is found from the Gulf of Maine to the Chesapeake Bay in the rest of the year. Apart from its seasonal occurrence on the Atlantic Shelf of Nova Scotia and Newfoundland and banks, it is probably best regarded as an occasional visitor to other Canadian waters. The coast of British Columbia in particular seems to be well north of its normal distribution on the west coast.

Le dauphin commun, *Delphinus delphis*, est très répandu dans les eaux des plate-formes continentales du monde entier, surtout dans les zones subtropicales et tempérées. Il se rencontre dans la zone tropicale là où les eaux relativement fraîches maintiennent la température à la surface entre 15° et 26°C. À l'été, il migre vers les régions tempérées sous des latitudes élevées où les eaux relativement chaudes lui permettent de prolonger son aire de répartition vers les pôles. Il se nourrit de proies concentrées en bancs pélagiques comme diverses espèces de calmar, d'éperlan, de hareng, de maquereau, de muge et de lanterne. Le mâle peut atteindre jusqu'à 260 cm de longueur et la femelle, 246 cm; toutefois, la plupart des adultes n'atteignent pas cette taille. L'adulte atteint la maturité sexuelle quand il a de cinq à sept ans. La gestation dure de dix à onze mois et la période de lactation, jusqu'à dix mois. La femelle met bas à presque tous les deux ans à un nouveau-né qui mesure de 75 à 90 cm de longueur. On ne connaît pas la durée de vie maximum. Le dauphin commun fait l'objet d'une exploitation relativement forte dans le cadre de la pêche de l'albacore à nageoires jaunes (*Thunnus albacares*) dans les eaux tropicales du Pacifique est; de plus, il a fait l'objet d'une chasse intense dans la mer Noire pendant de nombreuses années. Il semble assez abondant dans les eaux côtières de l'Amérique du Nord et n'est pas menacé de façon particulière. Il est possible qu'il se nourrisse dans des zones où des filets maillants et des filets dérivants à poisson de fond ne sont pas généralement mouillés en grand nombre à l'heure actuelle. Au large de la Nouvelle-Écosse et de Terre-Neuve, il peut-être abondant pendant un mois ou deux au cours de l'été; ce troupeau est tout probablement le même que celui présent dans les eaux s'étendant du golfe du Maine à la baie Chesapeake pendant le reste de l'année. À part sa présence saisonnière dans les eaux de la plate-forme continentale et des bancs au large de la Nouvelle-Écosse et de Terre-Neuve, le dauphin commun doit être considéré comme un visiteur occasionnel dans les autres secteurs canadiens. La côte de la Colombie-Britannique semble être en particulier bien au nord de son aire de répartition habituelle sur la côte ouest.

Key Words: Common Dolphin, Hourglass Dolphin, dauphin commun, *Delphinus delphis,* Cetacea, Delphinidae.

The Common Dolphin, *Delphinus delphis* Linnaeus 1758, is also variously known as the Saddleback or White-bellied Dolphin, especially on the Pacific coast, and sometimes as the Hourglass Dolphin. This animal (Figure 1) attains body lengths of up to 2.6 m and has a prominent dorsal fin. The body is typically dark purplish-brown dorsally, white ventrally, with shaded fields of grey and yellow forming an "hourglass" pattern along the flanks. After death the colour of the dorsal surface rapidly turns dark grey. The flippers are black, as is the area around the eye, and the dorsal surface of the beak or rostrum. There is a dark eye stripe in most adults.

The Common Dolphin is a slender, powerful swimmer, with a tall, broadly falcate dorsal fin. It is most easily recognized at sea by the extension of the pale vertical field up into the "cape" over the shoulders, with a resulting distinctive "criss-cross" in the

*Report accepted by COSEWIC 9 April 1991, no status designation required.

lateral pattern below the dorsal fin. Adults are usually from about 180 to 230 cm in length, although maximum lengths of 260 cm for males and 246 cm for females have been reported (Katona et al. 1983). Most animals occur in relatively small schools, with a modal value of about eight individuals (Winn 1982). Nevertheless, on occasion large aggregations are observed, sometimes including as many as 2000 animals (Winn 1982). Evans (1980) noted that it is frequently associated with flocks of Corey's Shearwaters (*Calonectis diomedia*) and Sooty Shearwaters (*Puffinus griseus*), Gannets (*Sula bassana*), Kittiwakes (*Rissa tridactyla*) and other medium and large gulls. It is rarely seen close to shore, but in certain seasons is abundant over the inner continental shelves of both coasts of North America. It has a global distribution in subtropical and warm temperate latitudes throughout both hemispheres. Distinct populations have been named, but at present it is best to regard these as local demes of a single species.

Although not commonly regarded as a resource animal, it was hunted for its meat until a few years ago by fishing communities of the Black Sea, especially the southern USSR and Turkey (IWC 1978); hunting probably still occurs in some coastal villages in the latter nation. It has ranked third, after Spinner Dolphins (*Stenella longirostris*) and Spotted Dolphins (*Stenella attenuata*), in mortality levels in the purse-seining fishery for Yellow-fin Tuna (*Thunnus albacares*) in the eastern tropical Pacific (IWC 1975). The species is said to be periodically or seasonally abundant off the coasts of Nova Scotia and Newfoundland (J. Lien, Memorial University, St. John's Newfoundland; personal communication), but there are few recent published data. Apart from this, it is normally considered as an unusual stray in other coastal waters of Canada (Anderson 1946), and appears to be directly or indirectly limited to seas where the surface temperatures average about 11 to 14°C. It does not seem to be under any general threat in North American waters.

Distribution

Western North Atlantic

Delphinus delphis is a relatively common inhabitant of the continental slope region between Cape Hatteras and southern Nova Scotia (Katona et al. 1983), with a particular concentration between about 100-200 m depth contours (Winn 1982; Selzer and Payne 1988). In the fall it is particularly abundant along the northern edge of George's Bank (Winn 1982). The relative abundance of the species decreased towards 36°N in the Cetacean and Turtle Assessment program (CeTAP) surveys (Winn 1982). Sergeant et al. (1970) noted that it was apparently common off the Atlantic coast of Nova Scotia in the vicinity of the Emerald, Sambro and Middle Ground Banks between August and October. Mercer (1973) sighted two schools on the Sable Island Bank in August 1970. It ranges to the coastal waters of southeastern Newfoundland (Sergeant and Fisher 1957; Sergeant et al. 1970; Reeves and Mitchell 1987; Lien, personal communication). Sergeant (1958) did not regard this as a common event in the 1950s, remarking that a local whaling captain who had worked those waters for 10 years had not seen the species until the summer of 1957. In July 1957, however, Sergeant was able to examine a specimen shot in Dildo Arm, Trinity Bay (47°32′N), and in August he sighted and confirmed the identity of two schools; 30 to 40 animals on the east side of Flemish Cap at 47°N, 44°32′W, and eight to 10 at 42°50′N, 50°05′W. The former would still seem to be the confirmed northern limital record for the western North Atlantic. The more usual northerly limit in the fall seems to be about 43 to 44°N (Winn 1982; Selzer and Payne 1988).

South of Cape Hatteras the species seems to be less common, although schools have been reported as far south as the lower eastern coast of Florida (Essapian 1954; Caldwell and Golley 1965; Layne 1965). Leatherwood et al. (1976) reported that it occurred also in the Gulf of Mexico and on the coastal shelf of Venezuela. Most published data relate to strandings only.

Eastern North Atlantic

Collett (1877) remarked that he had "hardly any doubt that *Delphinus delphis* occurred ... probably right up to Finmark". For many years this was repeated as the limital range for the species in the coastal waters of Western Europe, based on an unconfirmed sighting near the Loføten Islands in April 1961, and the presence of a skull in the Tromsø Museum. Jonsgaard (1962) was the first to challenge this assumption. He was able to confirm that a specimen reported by Collett (1912), held in the Bergen Museum, had indeed been caught off Alesund (approximately 62°30′N) in 1881, but the skull in Tromsø was without data and could have come from anywhere, even outside Norway. Jonsgaard (1962) also reported that no *Delphinus delphis* were sighted during extensive shipboard surveys for cetaceans off northern Norway. Watson (1981) stated that it occurred as far north as Iceland, but while it may stray that far north (63°30′ to 66°30′N) with tongues of North Atlantic Drift water on occasion, no evidence of general distribution in this region was reported by Sigurjonsson and Gunlaugsson (1988). In the course of some of the most extensive surveys for cetaceans ever carried out in the waters of the North Atlantic they found the species only off continental shelves and banks of the United Kingdom and Ireland.

Evans (1980, 1987) noted that British surveys showed that the species was concentrated off the

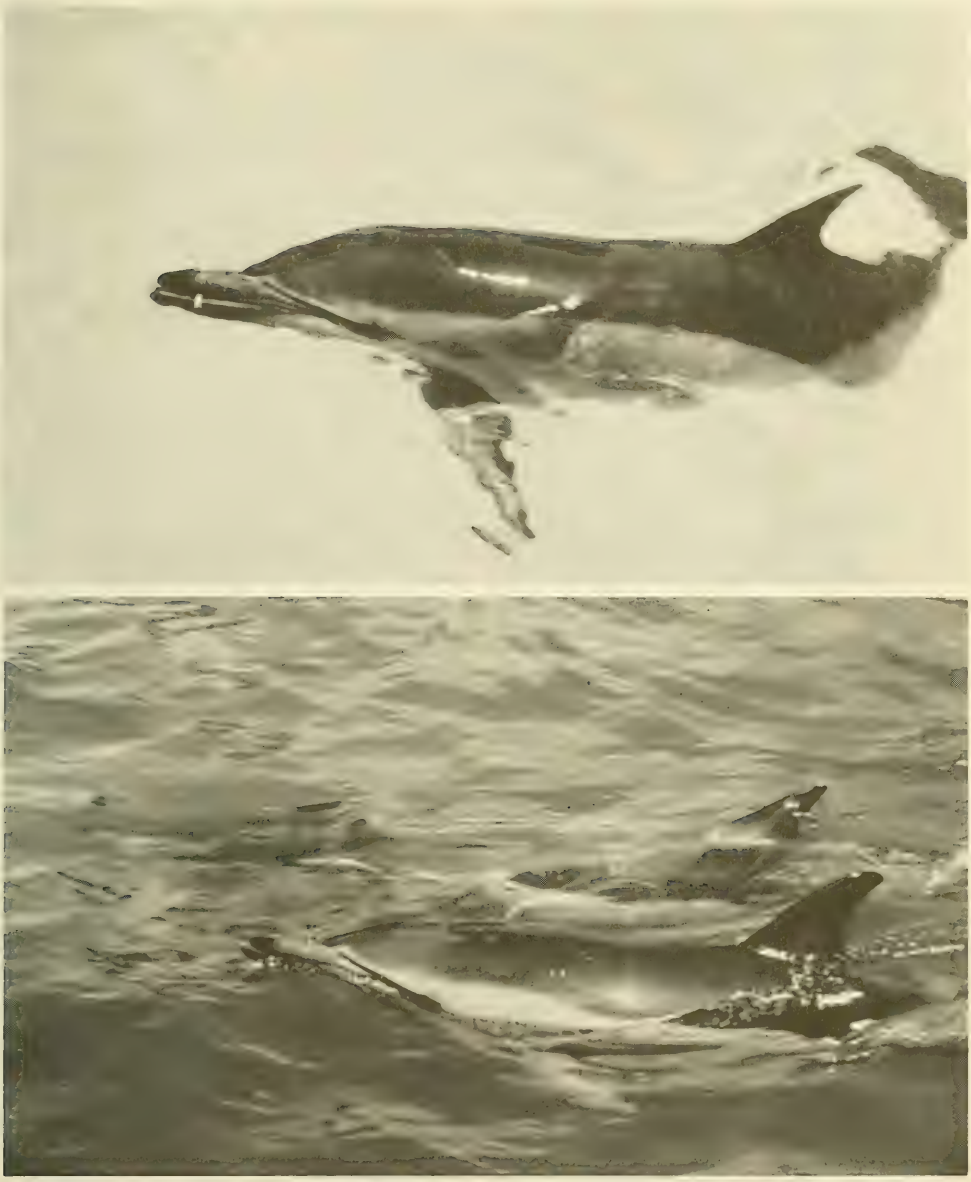


FIGURE 1. Female (A), and a pair (B) of Common Dolphins, *Delphinus delphis* (photographs by the author).

south and southwest coasts of Ireland, with seasonal penetration into the English Channel and off northeastern Scotland. In U.K. waters it is usually recorded between June and December, when warmer water is present in the English Channel and the Irish Sea (Evans 1980). The species is present off the coasts of Brittany in most months of the year (Duguy 1985). Duguy (1983) previously noted that it was rarely reported from the French coast of the English Channel (only 3.7% of 268 total strandings). Most of these were recorded from the Biscay coast in the winter and early spring. There were also few records the Mediterranean coast (7.1% of the total) and only four from Corsica. Cabrera (1914) and Casinos and Vericad (1976) reported it to be common off the coast of Spain and Sequeira (1990) indicated that it was the commonest cetacean off the coast of Portugal. Van Bree and Purves (1972) noted that it occurred off the coast of northwest Africa, as well as Europe. Viale-Pichod (1977) and Gihr and Pilleri (1969) provided data from the Mediterranean; the latter arguing that this population was distinctive morphometrically.

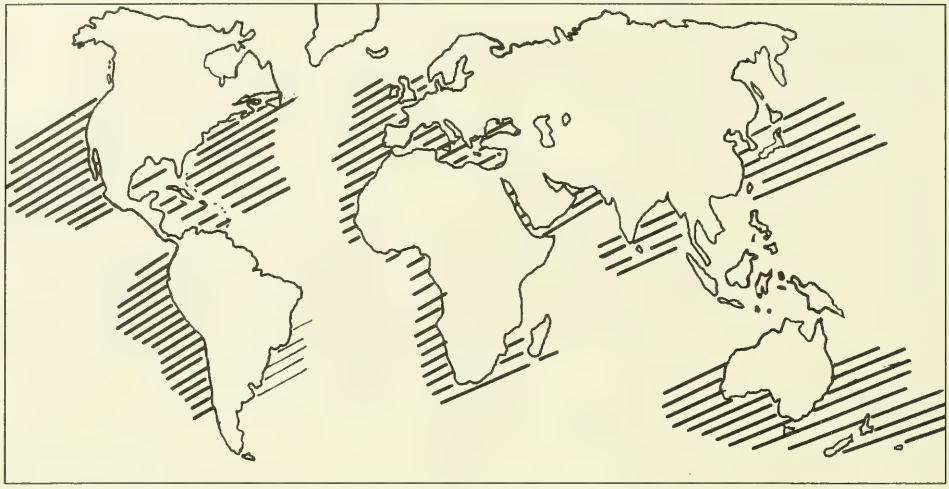


FIGURE 2. Shaded areas indicate approximate regions where *Delphinus delphis* has been reliably recorded. Strays will occur outside these areas, especially in warmer waters, and there may be other areas of concentration. Much material from the tropics has been inaccurately identified in the older literature and the records are unreliable.

Tomilin (1967) likewise considered *Delphinus delphis* of the Black Sea to be a unit population.

Eastern North Pacific

Watson (1981) and Gaskin (1985) illustrated the whole of the tropical and subtropical Pacific as inhabited by this species, but it is unlikely that the species is resident throughout this region, although schools may transit through virtually any area at some time or other. Probably the majority of all populations is concentrated along the coastal shelves, perhaps seasonally spilling out along convergence zones, if abundant prey are present. The truly pelagic ocean regions are more the domain of the spotted and spinner dolphins of the genus *Stenella*, rather than *Delphinus*.

The northern limital record on the west coast of North America is a stranding at Victoria, British Columbia (Leatherwood et al. 1982), but these authors pointed out that few sightings are made north of Point Conception, California. Scheffer and Slip (1948) included it in their list of cetaceans of Washington State on the basis of a photograph and a specimen of dubious identity recorded from Pacific Beach. Evans (1976) summarized data from tuna boat observers and research cruises and showed that the confirmed regular range covered a broad belt up to 600 nautical miles offshore from about 36°N to about 5°S in the vicinity of the Galapagos Islands. Evans recognized a clear break in distribution of *Delphinus delphis* extending for several hundred miles along the coast of Mexico in the vicinity of Acapulco, providing more evidence for north-south population segregation, possibly as a result of a westward salient of very warm (28°C +) oceanic surface waters touching the coast in this region (Evans 1976: Figures 4, 7). Given the range of apparent temperature preference of this species, it is likely to be restricted westwards by the cool waters of the south-flowing California Current and relatively low temperatures on the eastern edge of the North Pacific Drift in the northern part of its range, and by the distribution of the north-flowing cool waters of the Peru Current on the west coast of South America. Nevertheless, Bruyns (1971) and Aguayo (1975) have recorded it to 40°S on this coast. Some are taken incidentally in fishing gears on the coast of central Peru (Read et al. 1988).

The eastern North Pacific is the only region adjacent to North America where we have any data to support population segregation at present. Banks and Brownell (1969) concluded that two separate populations, long-snouted and short-snouted, were present in the coastal region of California, and applied the specific name *bairdii* to the former. Van Bree and Pilleri (1972) argued that long-snouted forms occurred in other parts of the world and unless all of them could be shown to belong to the same species, *bairdii* was not a suitable name. They noted that the name *Delphinus capensis* (Gray 1828), was taxonomically available and might be an applicable name for a discrete North Pacific population.

The single long-snouted population occurs only inside the 100 fathom line off southern California and in the Gulf of California, but Evans (1976) recognized a short-snouted form in the offshore regions of the eastern tropical Pacific, and two other short-snouted forms off southern California and in the

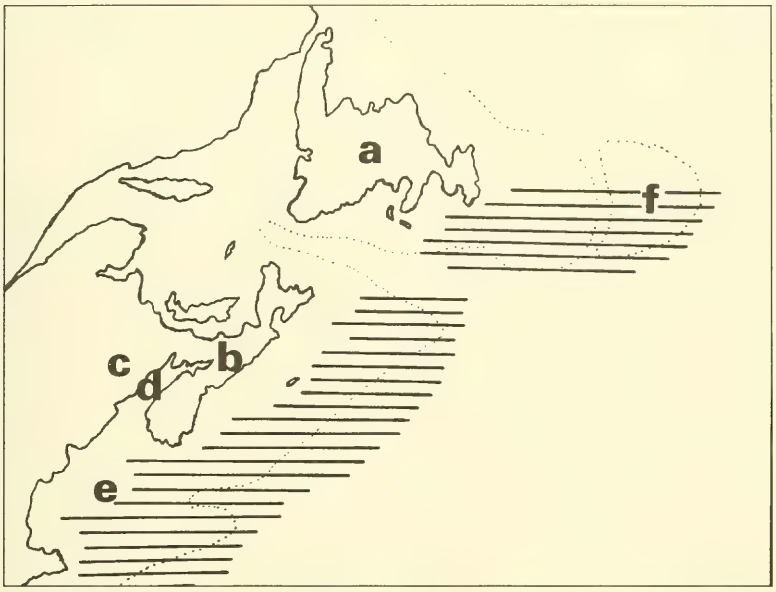


FIGURE 3. Shaded area indicates the regular, or seasonal, zones of occurrence of *Delphinus delphis* off eastern Canada. Strays will occur outside this area, and the range may extend further offshore than shown. a — Newfoundland, b — Nova Scotia, c — New Brunswick, d — Bay of Fundy, e — Gulf of Maine, f — Flemish Cap. [No range map for the west coast is shown as the species is only a rare stray north of Oregon].

Baja region respectively. Long and short-snouted herds sometimes overlapped, but there did not seem to be mixing. Evans (1976) speculated that statistically significant differences in the width of the right premaxilla and the greatest width of the external nares might be related to different vocalization capabilities along latitudinal clines as a result of adaptation to different prey species.

Protection

Small cetaceans were not protected under the original terms of the International Whaling Convention of 1946. In Canada, the Cetacean Protection Regulations of 1982, which were promulgated under the Fisheries Act, prohibit the catching or harassment of all species, including delphinids such as the Common Dolphin. Scientific sampling may be permitted under specific licences after thorough review of the application by the Department of Fisheries and Oceans.

Population Sizes and Trends

Western North Atlantic

Winn (1982) used sighting data from the CeTAP surveys of 1978 to 1982 to make some estimates of population sizes in the western North Atlantic. Although the survey did not include the Atlantic coast of Nova Scotia, this may introduce only a rather small additional error as winter surface temperatures on the shelf drop to 4 to 6°C. Under these circumstances, if the population stays on the shelf, all should be within the CeTap survey even in winter. The possibility remains that this segment may be more pelagic and move south. In that case, the size of the entire population may be considerably higher than the value derived by Winn (1982). The winter peak average was calculated at 31 124 ± 36 151. The maximum point abundance was estimated as 34 285 ± 71 487, in January 1981. While the confidence limits are very wide the averages are at least of the same order of magnitude. Nishiwaki (1972) gave a provisional estimate of the North Atlantic population at 30 000+, but this was based on very limited data.

Eastern North Atlantic

There are no available estimates of population size for the eastern North Atlantic.

Eastern North Pacific

Because of statistical problems with the survey data and the large variance in school size (5 to 3000), Evans (1976) declined to calculate a population estimate for the Californian-Central American shelf region. Later, the Scientific Committee of the International Whaling Commission (IWC 1978) used data provided by observers on tuna boats to estimate the approximate population size of *Delphinus del-*

phis in the eastern tropical Pacific (ETP) as 1 430 000 animals.

Habitat

Physical Characteristics

Delphinus delphis is essentially a denizen of the continental shelf and bank regions of the world (Gaskin 1968; Evans 1976; Winn 1982; Selzer and Payne 1988). Gaskin (1968) concluded that off New Zealand its range was bounded by the northern edge of the Subtropical convergence and a minimum water temperature of 14°C. Selzer and Payne (1988) found the species between 5° to 22.5°C, with a mean surface temperature of 11 ± 3.67°C. Winn (1982), summarizing the results from the CeTAP surveys of 1978 to 1982, gave the temperature range for sightings of this species as 1.0 to 24.0°C, with 90% between 7.0 to 22.4°C, an overall average of 13.7°C, and mode of 9°C. Given the dearth of cold water sightings in the rest of the surveyed areas of the North Atlantic it is natural to query the apparent records of this species in waters with temperatures as low as 1° to 5°C. If such temperatures result from relatively localized winter upwellings or coastal melt plumes, there is no reason why a dolphin of this size could not tolerate these temperatures for some days as long as it could continue feeding, since some animals certainly remain well north of 40°N during winter, at least until about February (Winn 1982). Schools may venture close to shore at any time of the year but are more often found between the 100 to 1000 m depth contours (Selzer and Payne 1988). Winn (1982) reported that the depth range over which all sightings were made was 26 to 5121 m, the average 844 m and the mode 91 m. Selzer and Payne (1988) found that 66% of all contacts were over zones with steepest subsurface topographic relief. All contacts occurred within a surface salinity range of 32 to 35‰.

Diet and Feeding

Western North Atlantic: Surface feeding by *Delphinus delphis* has not been observed frequently in any area. Winn (1982) observed feeding in only 2.4% of total sightings (n = 453) during the CeTAP surveys off the eastern seaboard of the United States, and then only in the vicinity of the Great South Channel along the edges of George's Bank. There is little information on stomach contents from animals taken or stranded in this region. Selzer and Payne (1988) noted that peak abundance of *Delphinus delphis* in the southern Gulf of Maine and over George's Bank appeared to coincide, at different times of year, with peak abundances of Mackerel, *Scomber scombrus*, Butterfish, *Poronotus triacanthus*, and Common Squid, *Ilex illecebrosus*. Sergeant (1958) found about 20 beaks of the latter animal in the stomach of a single specimen taken in southwestern Newfoundland.

Eastern North Atlantic: Evans (1982) noted that stranded or netted specimens examined on the British coasts had generally been feeding on herring, mackerel and cephalopods. A large number of stranded specimens were examined during the late 1970s and 1980s from the coasts of France by Collet (1981) and Desportes (1985), The dominant items of diet differ, depending if the calculation is based on numbers or weight. Nevertheless, the diet is varied. Among the most frequent prey species are Herring (*Clupea harengus*), Mackerel (*Scomber scombrus*), Horse Mackerel (*Trachurus trachurus*), Blue Whiting (*Micromeristius poutassou*), Whiting (*Merluccius* spp), Pilchard (*Sardina pilchardus*) and Anchovy (*Engraulis encrasicolus*). Cephalopods are also commonly taken, including *Loligo*, *Alloteuthis* sp., *Sepiola* sp. and sometimes *Sepia* sp.

Eastern North Pacific: Evans (1976) reported that the diet off southern California changed from mainly lantern fish and smelt in the spring and summer, to anchovies and squid in the winter months. *Loligo opalescens* made up about 99% of the total winter cephalopods eaten. Similarly, among the fish taken in winter, *Engraulis mordax* comprised 92% of the total, the balance being made up of *Merluccius productus* (6%) and *Cololabis saira* (25%). While the spring and summer diet was more varied, *Leuroglossus stilbius* accounted for 56% of the total, and *Seriphus politus* 19%. Of the relatively small quantities of cephalopods (23%) taken at this time of year onychoteuthids made up 85% of the total, and *Loligo opalescens* the remaining 15%. The remainder of the food consisted of 70% fish and 7% miscellaneous crustaceans.

Habitat Protection

There is little that can be done to protect this species in its broad range of distribution, other than to prohibit direct hunting, and to ensure that it is not at risk from surface drift nets, such as those set for squid in the Pacific.

Degree of Specialization and Consequent Vulnerability

In areas such as the Atlantic coast of France, the diet seems varied enough (Desportes 1985) for it to be able to withstand periodic over-fishing of some of its prey species. The apparent reliance on a much narrower spectrum of prey in the Californian coastal regions (Evans 1976) might indicate more vulnerability to the impact of local over-fishing of anchovies, although the alternative prey, lantern fishes, is likely to remain a seasonally abundant alternative.

Biology

Reproductive Biology

The male Common Dolphin attains sexual maturity at body lengths of about 170 cm in the Black Sea

(Kleinenberg 1956) and 190 to 200 cm in the waters of the northeast Atlantic off the coast of France (Collet 1981). Uncertainty remains about the age at which this occurs because of problems of interpretation of laminae in the dentine and cementum, although Collet (1981) believed it to be at 6+ years in the male, and 5 to 7 years in the female. The estimate of three years for sexual maturity in both sexes, published by Sleptsov (1940), was not based on a definitive method of age determination and can be discounted as too low.

The gestation period is generally agreed to be 10 to 11 months, but there is disagreement among workers concerning the length of the period of lactation, varying from 5 to 6 months (Leatherwood et al. 1982), to at least 10 months (Collet 1981). The mean calving interval has been estimated as 1.3 years (Sleptsov 1940) or two years (Collet 1981). Estimates of body length at birth range from 75 to 80 cm (Mitchell 1975) to 90 cm (Collet 1981). The latter suggested that the peak period for breeding in the eastern North Atlantic population was during May and June. Winn (1982) reported relatively few sightings of calves in the southern Gulf of Maine and over the central seaboard shelf region in any season (60 sightings in three years): when seen, calves tended to occur in the larger schools (20+ animals). Sergeant et al. (1970) reported that a female taken in August 1954 off Nova Scotia was lactating and accompanied by a calf. Mercer (1973), recorded another lactating specimen taken off North Carolina in April 1967. Calves in the Black Sea were usually seen in the summer months (Sleptsov 1940) and in the spring-summer months off the coast of southern California (Leatherwood et al. 1976).

Movements

Northwest Atlantic: Winn (1982) noted that annual movements of *Delphinus delphis* in the coastal regions of eastern North America were still poorly known. During the CeTAP surveys referred to earlier, abundance was lowest in the summer. The most likely explanation , since numbers did not rise elsewhere in United States waters, is that a significant segment of the population follows the edge of the North Atlantic Drift as the summer progresses, and in July-September is distributed along the Atlantic coastal shelf of Nova Scotia and Newfoundland, beyond the northern limit of the CeTAP transects.

Northeast Atlantic: Evans (1980) summarized what little is known of the movements around northwestern Europe. There appears to be a movement into the southwest coastal regions of Ireland and southern England in the summer, associated with movements of mackerel populations. A parallel movement of Common Dolphins past the north of Scotland into the northern North Sea in August coincides with the migration of spawning herring.

Northeast Pacific: Evans (1976) noted that although *Delphinus delphis* was present in the coastal waters of southern California all the year round, clear peaks could be recognized in January, June and September-October. Because at least two or three distinct sub-populations have been recognized in the region, the biological significance of such peaks must be interpreted with caution. Common Dolphins have also been observed to follow major features of bottom topography such as escarpments, and make regular return movements (as recorded by radio-telemetery, Martin et al. 1971) over periods of days or weeks.

Behavioural Adaptability

The Common Dolphin has been kept in seaquaria [eg. in New Zealand (Gaskin 1972)], but the results have not generally been very successful. High mortalities have been recorded. While the diet varies greatly from one part of the world to another, the larger concentrations of this species tend to depend on a relatively small number of prey species in most areas. In the eastern tropical Pacific the species suffers significant mortalities in purse seining operations for tuna, and in coastal and shelf waters is vulnerable to set and drift net fisheries. It does not seem to be able to learn to avoid these gears very readily, possibly because it only uses echolocation when hunting food in relatively deep waters where natural obstructions would not usually be anticipated. A high proportion may be entangled at night, when the netting is almost invisible. It is not a species that one might expect to show great ability to adapt to major changes in its habitat. It seems to be closely tied to specific, abundant schooling fish and squid of about 10 to 30 cm in length, and may actually be attracted to nets where such fish are entangled. Nevertheless, its distribution is so extensive that it is unlikely to be threatened on a global scale in the foreseeable future other than through the impact of net entanglements, and over a longer time period, intensive competition with man for its prey species.

Limiting Factors

Delphinus delphis is essentially a coastal shelf species or an inhabitant of relatively warm ocean frontal zones, and strays only occasionally into shallow inshore waters. Globally its range is vast, although there may be recognizable sub-populations which have relatively low rates of genetic interchange.

The Common Dolphin used to be seasonally common on the coasts of Belgium until the mid-1950s (De Smet 1974; Van Bree 1976), since which time it has declined rapidly in apparent abundance. Evans (1980) speculated that this might be the result of changes in regional oceanography, or the result of excessive incidental captures in fishing gear such as gill nets.

Evans (1976) observed that while this species ranked third in tuna purse-seine mortalities after *Stenella longirostris* and *Stenella attenuata*, the 1973 incidental kill was of the order of 21 000 animals, based on an estimate from the 14.8% of the total purse-seine sets in which *Delphinus delphis* was captured.

As long as the Common Dolphin is not threatened by specific fishing gear such as purse-seines and surface drift nets, it seems unaffected by shipping. It is undeterred by cargo ships, fishing vessels, or pleasure craft, and frequently comes to ride the bow wave.

Special Significance of the Species

Unlike the Harbour Porpoise (*Phocoena phocoena*) and the White-sided and White-beaked dolphins, *Lagenorhynchus acutus* and *Lagenorhynchus albirostris*, the Common Dolphin has a world-wide distribution. While it is usually found in coastal shelf waters, it may also be encountered hundreds of miles from land in the tropics and subtropics. To lovers of all marine life it has special symbolic status, being the dolphin of the coinage, pottery and friezes of Ancient Greece, Rome and other early Mediterranean powers.

Evaluation

The only significant penetration of Canadian waters by this species seems to occur on the Scotia Shelf and on the continental shelf off Newfoundland during summer and fall months when water temperatures exceed 11°C (Sergeant et al. 1970; Reeves and Mitchell 1987). Although it has suffered significant mortality in the tuna purse-seining industry of the eastern Tropical Pacific, there are few data on similar fishing gear mortality in the warmer waters of the Atlantic. There is currently no evidence of a major threat to this species in Canadian waters, and no requirement for any classification by COSEWIC at this time.

Acknowledgments

I thank Dr. R. R. Campbell of the Department of Fisheries and Oceans, Ottawa, and two anonymous reviewers, for reading the draft manuscript and giving me their constructive comments. Financial support for production of this report was made possible by World Wildlife Fund (Canada) and the Department of Fisheries and Oceans.

Literature Cited

Aguayo, A. L. 1975. Progress report on small cetacean research in Chile. Journal of the Fisheries Research Board of Canada 32: 1123–1143.

Anderson, R. M. 1946. Catalogue of Canadian recent mammals. National Museum of Canada Bulletin 102: 1–238.

Banks, R. C., and **R. L. Brownell.** 1969. Taxonomy of the common dolphins of the eastern Pacific Ocean. Journal of Mammalogy 50: 262–271.

Bree, P. J. H., van. 1977. On former and recent strandings of cetaceans on the coast of the Netherlands. Zeitschrift für Säugetierkunde 42: 101–107.

Bree, P. J. H., van, and **P. E. Purves.** 1972. Remarks on the validity of *Delphinus bairdii* (Cetacean Delphinidae). Journal of Mammalogy 53: 372–374.

Bruyns, W. F. M. 1971. Field guide of whales and dolphins. Uitgeverij Tor/n.v. Uitgeverji v.h. C.A. Mees, Amsterdam.

Cabrera, A. 1914. Fauna Iberica. Mamiferos. Museo Nacional de Ciencias Naturales. xviii + 441 pages.

Caldwell, D. K., and **F. B. Golley.** 1965. Marine mammals from the coast of Georgia to Cape Hatteras. Journal of the Elisha Mitchell Scientific Society 81: 24–32.

Casinos, A., and **J.-R. Vericad.** 1976. The cetaceans of the Spanish coasts: a survey. Mammalia 40: 267–289.

Collet, A. 1981. Biologie de Dauphin commun *Delphinus delphis* L. en Atlantique Nord-est. Thèse: Docteur de troisième cycle en biologie animale, L'Université de Poitiers. 156 pages.

Collet, R. 1877. Bemaerkninger til Norges Pattedyrfauna. Nyt Magazine for Naturvidenskaberne 1877. 22: 54–168.

Collet, R. 1912. Norges Pattedyr. Kristiana, 1911–12, 744 pp.

Desportes, G. 1985. La nutrition des odontocetes en Atlantique Nord-est (côtes Françaises-iles Feroë). Thèse: Docteur de troisième cycle en biologie animale, L'Université de Poitiers, 190 pp.

Duguy, R. 1983. Les cétacés des côtes de France. Annales de la Société des sciences naturelles de Charente-Maritime. Supplement 1983: 1–112.

Duguy, R. 1985. Rapporte annuel sur les Cétacés et Pinnipeds trouvés sur les côtes de France. XV-Année 1984. Annales de la Société des sciences naturelles de Charente-Maritime 7: 349–364.

Essapian, F. S. 1954. A common dolphin – uncommonly marked. Everglades Natural History 2 (4): 220–222.

Evans, P. G. H. 1980. Cetaceans in British waters. Mammal Review 10: 1–52.

Evans, P. G. H. 1982. Associations between seabirds and cetaceans: a review. Mammal Review 12: 187–206.

Evans, P. G. H. 1987. The natural history of whales and dolphins. Facts on File Publications, New York and Oxford. 343 pages.

Evans, W. E. 1976. Distribution and differentiation of stocks of *Delphinus delphis* Linnaeus in the northeastern Pacific. Scientific Consultation on Marine Mammals, FAO of the UN, Bergen, Norway, December 1976, document SC No. 18. 72 pages.

Gaskin, D. E. 1968. Distribution of Delphinidae (Cetacea) in relation to sea surface temperatures off eastern and southern New Zealand. New Zealand Journal of Marine and Freshwater Research 2: 527–534.

Gaskin, D. E. 1972. Whales, dolphins and seals; with special reference to the New Zealand region. Heinemann Educational Books, Auckland. 200 pages.

Gaskin, D. E. 1985. The ecology of whales and dolphins. Heinemann Educational Books, London and Exeter, N. H. (Second printing, revised). 459 pages.

Gihr, M., and **G. Pilleri.** 1969. On the anatomy and biometry of *Stenella styx* Grey and *Delphinus delphis* L.

(Cetacea: Delphinidae) of the western Mediterranean. Investigations on Cetacea 1: 15–65.

International Whaling Commission. 1975. Report on the meeting on small cetaceans, Montreal, April 1-22, 1974. Journal of the Fisheries Research Board of Canada 32: 889–983.

International Whaling Commission. 1978. Report of the Scientific Committee, 28th Annual Meeting. Report of the International Whaling Commission 28: 38–92.

Jonsgaard, A. Aa. 1962. On the species of dolphins found on the coast of northern Norway and adjacent waters. Norsk Hvalfangsttidende 51: 1–12.

Katona, S. K., V. Rough, and **D. T. Richardson.** 1983. A field guide to the whales, porpoises and seals of the Gulf of Maine and eastern Canada — Cape Cod to Newfoundland. Scribner's Sons, New York.

Kleinenberg, S. E. 1956. [Mammals of the Black and Azov seas]. Izdatel'ctvo Akademiya Nauk Moskva, SSSR. 288 pages.

Layne, J. N. 1965. Observations on marine mammals in Florida waters. Bulletin of the Florida State Museum 9: 131–181.

Leatherwood, S., D. K. Caldwell, and **H. E. Winn.** 1976. Whales, dolphins and porpoises of the western North Atlantic: A guide to their identification. National Marine Fisheries Service Technical Report Circular Number 396, Seattle, Washington. 176 pages.

Leatherwood, S., R. R., Reeves, W. F. Perrin, and **W. E. Evans.** 1982. Whales, dolphins and porpoises of the eastern North Pacific: A guide to their identification. National Marine Fisheries Service Technical Report Circular Number 444, Seattle, Washington. 245 pages.

Martin, H., W. E., Evans, and **C. A. Bowers.** 1971. Methods for radio tracking marine mammals in the open sea. 44-IEEE, 1971 Engineering in the Ocean Environment Conference, pages 44–49.

Mercer, M. C. 1973. Observations on distribution and intraspecific variation in pigmentation patterns of odontocete Cetacea in the Western North Atlantic. Journal of the Fisheries Research Board of Canada 30: 1111–1130.

Mitchell, E. 1975. Porpoise, dolphin and small whale fisheries of the world, status and problems. International Union for the Conservation of Nature and Natural Resources, Morges, Switzerland, Monograph Number 3. 129 pages.

Nishiwaki, M. 1972. General Biology. Pages 3-204 *in* Mammals of the sea. *Edited by* S. H. Ridgway. Charles C. Thomas, Springfield, Pennsylvania.

Read, A. J., K. Van Waerebeek, J. C. Reyes, J. S. McKinnon and **L. C. Lehman.** 1988. The exploitation of small cetaceans in coastal Peru. Biological Conservation 46: 53–70.

Reeves, R. R., and **E. Mitchell.** 1987. Cetaceans of Canada. Department of Fisheries and Oceans Publication, Underwater World Number 59. 27 pages.

Scheffer, V. B., and **J. W. Slipp.** 1948. The whales and dolphins of Washington State with a key to the cetaceans of the west coast of North America. American Midland Naturalist 39: 257–337.

Selzer, L. A., and **P. M. Payne.** 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. Marine Mammal Science 4: 141–155.

Sergeant, D. E. 1958. Dolphins in Newfoundland waters. Canadian Field-Naturalist 72: 156–159.

Sergeant, D. E., and **H. D. Fisher.** 1957. The smaller Cetacea of eastern Canadian waters. Journal of the Fisheries Research Board of Canada 14: 83–115.

Sergeant, D. E., A. W. Mansfield, and **B. Beck.** 1970. Inshore records of Cetacea for eastern Canada, 1949-68. Journal of the Fisheries Research Board of Canada 27: 1903–1915.

Sigurjonsson, J., and **T. Gunnlaugsson.** 1988. Distribution and abundance of cetaceans in Icelandic and adjacent waters from sightings surveys conducted in June-July 1987. Conseil international pour l'exploration de la Mer, Charlottenlund Slot, Denmark. Document 1988/N: 14.

Siqueira, M. L. 1990. Gillnets and cetacean mortality in Portugal. IWC Symposium on mortality of cetaceans in passive fishing nets and traps. La Jolla, California, October 20-21, 1990.

Sleptsov, M. M. 1940. Determination of the age of *Delphinus delphis* L. Bulletin de la Société de Nature (Moscou) 49: 43–51.

Smet, W. M. A. 1974. Inventaris van de Walvisachtigen (Cetacea) van de Vlaamse kust en di Schelde. Bulletin de l'Institut royale des sciences naturelles de Belgique 50: 1–156.

Tomilin, A. G. 1967. Cetacea: Volume 9, Mammals of the USSR and adjacent countries. Translation of 1957 Russian edition by the Israel Program for Scientific Translation, *Edited by* V. G. Heptner, Jerusalem.

Viale Pichod, D. 1977. Ecologie des cétacés en Méditerrané nord-occidentale: leur place dans l'écosystème, leur réaction à la pollution marine par les metaux. Thèse de doctorae d'état des sciences naturelles, à l'université Pierre et Marie Curie (Paris VI). 312 pages.

Watson, L. 1981. Sea guide to whales of the world. Nelson Canada Limited, Scarborough, Ontario.

Winn, H. E. 1982. A characterization of marine mammals and turtles in the mid and North American areas of the U.S. Outer Continental Shelf. Final Report of Cetacean and Turtle Program (CeTAP), contract No. AA551-CT8-48 to the Bureau of Land Management, U.S. Department of the Interior, Washington, D.C.

Accepted 31 May 1991

Status of the Atlantic White-sided Dolphin, *Lagenorhynchus acutus*, in Canada*

David E. Gaskin

Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1

Gaskin, David E. 1992. Status of the Atlantic White-sided Dolphin, *Lagenorhynchus acutus*, in Canada. Canadian Field-Naturalist 106(1): 64–72.

The White-sided Dolphin, *Lagenorhynchus acutus*, occurs in cool temperate waters (average about 7 to 12°C) on both sides of the North Atlantic Ocean, and around Iceland and the Faeroe Islands. On the eastern seaboard of North America its range extends from 37°N to perhaps 71°N. Northern limital records may be of that form of the White-beaked Dolphin (*Lagenorhynchus albirostris*) which has a dark rostrum. The maximum point estimate of population size for United States shelf waters in 1982 was 46 436. The area surveyed in providing this estimate ended at the southern extremity of Nova Scotia; there is no estimate of population size in eastern Canadian waters, but the total might be in the tens of thousands. The White-sided Dolphin is essentially a denizen of the Continental Shelf waters, and is most abundant in areas of steepest subsurface topographic relief. The average mean depth for sightings off the United States was 165 m. At birth, calves are about 109 to 114 cm in length, with the peak of births in June through July and the range extending from May to early August. Sexual maturity in females is attained at about six to eight years of age and standard body length of 201 to 222 cm. The equivalents for males are eight to nine years and 210 to 244 cm respectively. The gestation period appears to be about 11 months, and lactation may last 18 months. The total length of the reproductive cycle may be at least 2.5 years. Maximum age is unknown. The oldest specimen from Western Atlantic samples was a female estimated to be 27 years of age. The region of maximum abundance off the northeast United States and southeast Canada seems to be the Gulf of Maine, where the main item of food is assumed to be sand lance. Other common prey include Silver Hake (*Merluccius bilinearis*), herring (*Clupea harengus*) and Common Squid (*Ilex illecebrosus*). Potential threats to this species include groundfish gill nets off eastern USA and Canada, salmon drift nets in the Labrador Sea, and possible spills from future offshore oil development. Nevertheless, there seem to be no direct threats to the species at present and no recommendations on status are made.

Le dauphin à flancs blancs, *Lagenorhynchus acutus*, fréquente les eaux froides tempérées (dont la température moyenne varie de 7° à 12°C) des côtes de l'Atlantique nord, de l'Islande et des îles Féroé. Sur la côte est de l'Amérique du nord, son aire de répartition s'étend de 37° de latitude nord jusqu'à peut-être 71° de latitude nord quoique les données sur la répartition dans les eaux septentrionales peuvent se rapporter au le dauphin à nez blanc (*Lagenorhynchus albirostris*) dont le rostre est aussi foncé. En 1982, l'estimation ponctuelle maximale des effectifs dans les eaux américaines de la plate-forme continentale se situait à 46 436 individus. La zone du relevé se terminait à la pointe sud de la Nouvelle-Écosse. On ne dispose pas d'estimations des effectifs dans les eaux canadiennes, mais le total peut se situer dans les dizaines de milliers d'individus. Avant tout un habitant des eaux côtières intérieures de la plate-forme, le dauphin à flancs blancs est plus abondant dans les régions où le fond marin est très accidenté. Dans les eaux américaines, la profondeur moyenne fréquentée par les individus observés s'éléve à 165 m. A la naissance, le petit mesure de 109 à 114 cm. La période de pointe de la mise bas couvre les mois de juin et de juillet mais peut aller de mai au début d'août. La femelle atteint la maturité sexuelle vers l'âge de six à huit ans quand la longueur standard du corps va de 201 à 222 cm. Quant au male, il atteint la maturité sexuelle vers huit à neuf ans quand la longueur du corps va de 210 à 244 cm. La période de gestation dure environ 11 mois et la lactation environ 18 mois. Le cycle reproducteur dure au moins 2,5 ans. On ne connaît pas l'age maximum. Le plus vieux spécimen provient d'échantillons recueillis dans l'Atlantique ouest, soit une femelle d'environ 27 ans. Il semble que le golf du Maine soit la région d'abondance maximale où le dauphin à flancs blancs se nourrit supposément de laçon du nord. D'autres proies communes comprennent le merlu argenté (*Merluccius bilinearis*), le hareng (*Clupea harengus*) et l'encorent nordique (*Ilex illecebrosus*). La plus importante menace auquelle fait face cette espèce est probablement les filets des poisson du fond au large des côtes est américaines et canadiennes, les fillets dérivants de saumon dans la mer de Labrador et possiblement, un déversement d'huile de développements pétrolifères littoraus futurs. Il ne semble toutefois pas exister de menaces directes pour l'espèce en ce moment et l'auteur ne présente aucune recommandation sur son statut.

Key Words: Atlantic White-sided Dolphin, dauphin à flancs blancs, *Lagenorhynchus acutus*, Cetacea, Delphinidae.

The Atlantic White-sided Dolphin, *Lagenorhynchus acutus* (Gray 1828), averages about 2.5 m in length, is dark purplish gray-black dorsally, and pure white ventrally (Figure 1). The flanks are light gray, but with a most distinctive ochreous yellow elongate patch that starts below the fin and extends

*Report accepted by COSEWIC 9 April 1991, no status designation required.

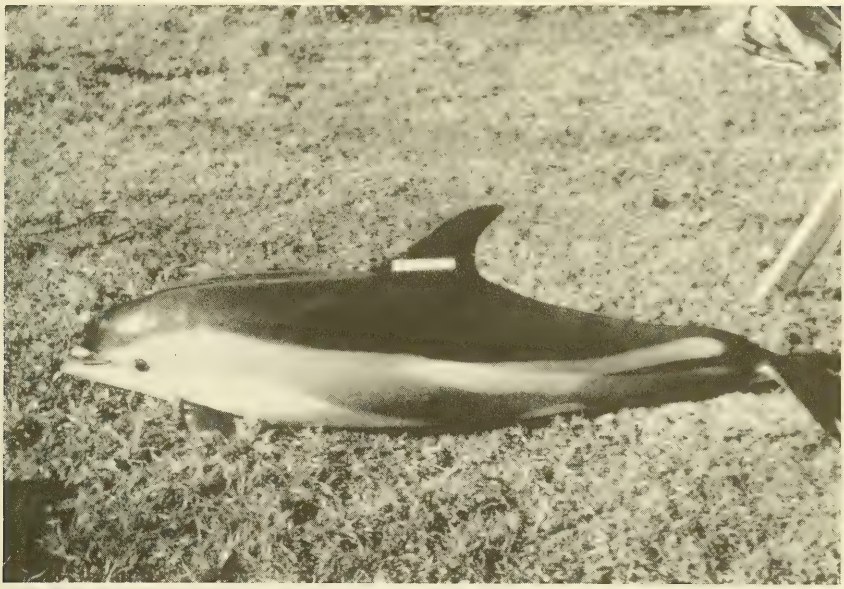


FIGURE 1. Atlantic White-sided Dolphin, *Lagenorhynchus acutus* (Photograph taken by Per Berggren, Department of Zoology, University of Guelph, by permission).

to the side of the tail stalk. The large, strongly curved dorsal fin is distinctive at sea. The "beak" is very short, and its upper surface is always gray-black.

Lagenorhynchus Gray 1846, is a genus of robust, agile dolphins found in cool temperate waters of both hemispheres. Six species are currently recognized (Fraser 1966) although Bierman and Slijper (1947, 1948) formerly concluded, on the basis of limited material, that all Southern Ocean morphological forms were essentially conspecific. The three species of the southern hemisphere are *Lagenorhynchus cruciger* (Quoy and Gaimard 1824), the Hour-glass Dolphin, which seems to be nearly circumpolar in the waters adjacent to the Antarctic Convergence; *Lagenorhynchus australis* (Peale 1848), Peales, or the Black-chinned Dolphin, which is restricted to the coastal shelf of southern South America and the Falklands Shelf, and *Lagenorhynchus obscurus* (Gray 1828), the Dusky Dolphin, which occurs off temperate South America, South Africa, Kerguelen Island, New Zealand and several other sub-Antarctic Islands, but not in Australian waters. In the northern hemisphere, a single species, *Lagenorhynchus obliquidens* Gill 1865, the Pacific White-sided Dolphin, occurs in cool waters from Japan to Alaska, and south to southern California. Two species are found in the North Atlantic; *Lagenorhynchus albirostris* (Gray 1846), the White-beaked Dolphin, has the more northerly distribution of the two, regularly occurring from Davis Strait to Nova Scotia, and from western Norway to the Barents Sea.

Lagenorhynchus acutus, the Atlantic White-sided Dolphin, is the second North Atlantic species. It attains a maximum adult length of about 280 cm, although among 65 animals examined by Sergeant et al. (1980) the largest male was 267 cm and the largest female 243 cm, with corresponding body weights of 234 kg and 182 kg. *Lagenorhynchus acutus* is basically blackish on its dorsal and dorso-lateral surfaces and white ventrally. Enclosed within the dark area of the flank is an elongate, tapering zone of white and ochreous yellow extending from below the leading edge of the large, curved dorsal fin to the constriction of the caudal peduncle. Gray shading around the pale markings is present, but not easily visible at sea. The superficially similar White-beaked Dolphin lacks the white and yellowish markings; instead the flanks bear two lateral patches of gray pigment, one anterior to and the other posterior to the dorsal fin. The rostrum (beak) of *Lagenorhynchus acutus* is always black, but this is not a particularly good field mark, partly because it is not easy to discern at any distance in average seas, and partly because the beak of the so-called White-beaked Dolphin is frequently dark in specimens from the western North Atlantic (Leatherwood et al. 1976) and off northern Norway (Jonsgaard 1962). The white-beaked form is more typical of the south-eastern part of the North Atlantic, especially around the United Kingdom (Evans 1987).

Distribution

Western North Atlantic (Figure 2)

The great majority of all sightings of this dolphin have been recorded from the coast out to the 100 m depth contour (Winn 1982; Selzer and Payne 1988). The southernmost limit seems to be reached at about latitude 37°N on the shelf east of Chesapeake Bay during the early spring. Extensive surveys made in 1978 to 1985 (Winn 1982; Selzer and Payne 1988) indicate that this is the normal range limit. Most sightings were concentrated on the shelf off Cape Cod and in the southern part of the Gulf of Maine. This is more representative of the northern limits of the surveys by the United States agencies rather than of the range of White-sided Dolphins, as was noted by the above authors. The species is a regular summer and fall visitor to the lower Bay of Fundy (Kraus and Prescott 1981; Gaskin 1983; Beatty 1989). Specific records for the Atlantic coast of Nova Scotia are scarce; I recorded schools on several occasions off La Have and on the edge of the Chester Basin in the early 1970s, always in summer. Sergeant et al. (1980) listed three stranding records from Sable Island and St. Margaret's Bay. Those on Sable Island were first reported by Sergeant et al. (1970), Sergeant et al. (1980) also mapped several sightings and strandings in the St. Lawrence as far west as the mouth of the Saguenay River in 1976 and 1978. The same authors, supplementing earlier records by Sergeant and Fisher (1957) and Mercer (1973), added more records from southeastern Newfoundland, southern Labrador and the northern part of Flemish Cap at 52°30'N 43°31'W, which is probably the most easterly record for the western North Atlantic. The most northerly limit of the distribution of *Lagenorhynchus acutus* is debatable. While several secondary sources, e.g., Leatherwood et al. (1976), Katona et al. (1983), Gaskin (1985) and Evans (1987), assumed a distribution extending far into Davis Strait proper, the evidence for this rested on sight records only, e.g., at Kangeq, near Godthaab (Jensen 1928). Mercer (1973) had already concluded that a similar record by Brown (1868), attributed to Gray (1866), was an error. Evans (1987) stated that it had been recorded as far north as Umanaq (Umanak), at latitude 71°N, but gave no source. F. Kapel (in Mitchell 1975), reported nine White-sided Dolphins taken in West Greenland between 1964 and 1966, although Lear and Christensen (1975) reported none among the 573 Harbour Porpoises taken in salmon drift nests off West Greenland from Nanortalik (60°N) to Umanak (71°N) between July and October 1972. Recently, Stenson and Reddin (1990), reporting on the results of experimental salmon tagging using drift nets from the southern Grand Banks to West Greenland, noted White-sided Dolphins being captured in the Newfoundland Basin in the spring, and in the shelf waters of the Labrador Sea. They recorded none on the Grand Banks, or off West Greenland.

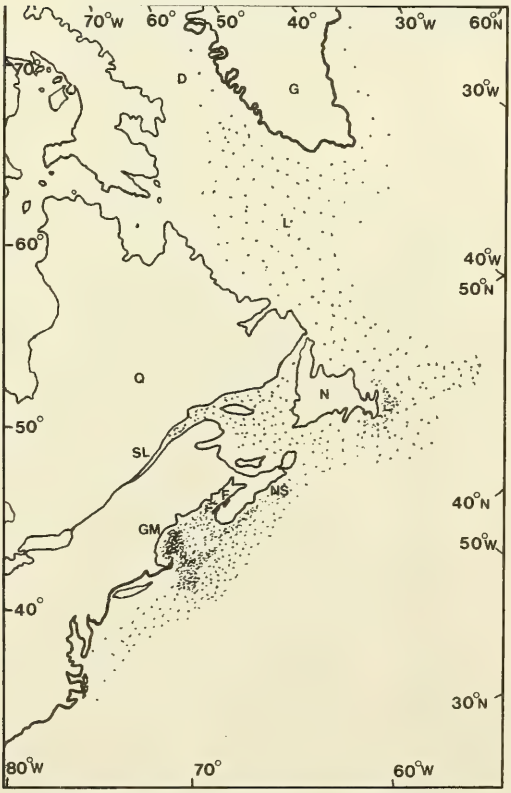


FIGURE 2. Approximate distribution of *Lagenorhynchus acutus* in the western North Atlantic. G — Greenland, N — Newfoundland, NS — Nova Scotia, Q — Quebec, SL — St. Lawrence, F — Bay of Fundy, GM — Gulf of Maine, D — Davis Strait, L — Labrador Sea. The intensity of stippling indicates apparent relative density without allowance for seasonal shifts in distribution based on present limited information.

Eastern North Atlantic (Figure 3)

Most records of the White-sided Dolphin from the eastern North Atlantic are from northwestern Europe. While the species was not listed from Iceland by Saemundsson (1939), it was reported by Evans (1987), and Sigurjonsson and Gunnlaugsson (1988) recorded 133 sightings totalling 794 animals during transect surveys in 1987 in the region bounded by east Greenland, Iceland, western Norway, and the British Isles. Well over 80% of White-sided Dolphins were seen between western Norway, Iceland and the British Isles. Evans (1980, 1987) noted that most sightings and strandings in United Kingdom records were from north and northeast Britain and in the approaches to the Irish Channel.

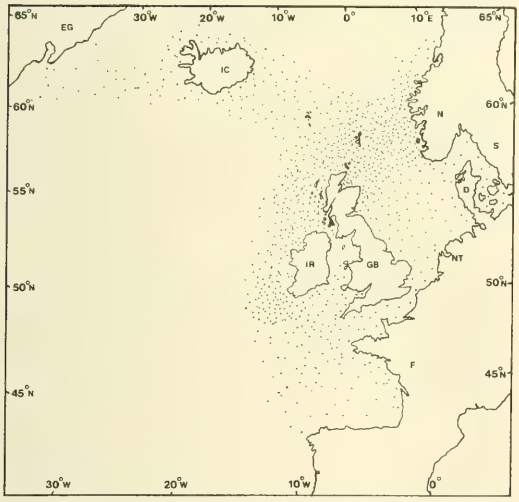


FIGURE 3. Approximate distribution of *Lagenorhynchus acutus* in the eastern North Atlantic. EG — East Greenland, IC — Iceland, N — Norway, S — Sweden, IR — Ireland, GB — Great Britain, D — Denmark, NT — Netherlands, F — France. The intensity of stippling indicates apparent relative density without allowance for seasonal shifts in distribution based on present limited knowledge.

Mitchell (1975) reported a specimen from Angmagssalik, in East Greenland. This would seem to be the limital record for the northwestern distribution of the species in the eastern North Atlantic. Reports of its occurrence along the northwest coast of Norway by Hjort (1902) have been attributed by Jonsgaard (1962) to mis-identifications of White-beaked Dolphins which lack the pale rostrum often stated to be characteristics of the species. Jonsgaard and Nordli (1952) had previously verified coastal records for Norway only as far north as Trondheim, about 63°N.

The British records have been discussed by Harmer (1927), Fraser (1934, 1946, 1953, 1974), and most recently by Evans (1980, 1987). Its abundance, as indicated by both sightings and strandings, appears to be much lower in the relatively shallow waters of the North Sea and English Channel than further north and west (Evans 1980). Winn (1982) and Selzer and Payne (1988) also concluded that the species is associated primarily with continental shelf, rather than inshore waters. There are few records from the Netherlands (Van Utrecht and Husson 1968) and other countries. Duguy (1983) considered the White-sided Dolphin an uncommon species on the Atlantic coast of France. None are recorded from the coasts of Spain (Casinos and Vericad 1976) nor from the Mediterranean Sea (Duguy 1983; Viale-Pichod 1977). Watson (1981) referred (without attribution) to a record from Portugal. He also cited an even more surprising report of a specimen from the Adriatic Sea by Toschi (1965, *not seen*). This is so far from the apparent normal limital range of the species that it seems likely to have been a specimen discarded by an Italian fishing vessel that had been operating in Atlantic waters.

Protection

Small cetaceans such as the White-sided Dolphin are not protected under the original terms of the International Whaling Convention of 1946. A number of countries, including Canada, have introduced specific cetacean protection regulations to govern exploitation of species within their zone of jurisdiction. In Canada, the Cetacean Protection Regulations of 1982, promulgated under the standing Fisheries Act, prohibit the catching or harassment of all species, including the White-sided Dolphin. Scientific study, and in some cases scientific sampling, is permitted, but only under specific licences. These are reviewed bi-annually by the Department of Fisheries and Oceans, and the Advisory Committee on Whales and Whaling, which provides advice directly to the Minister of Fisheries.

Population Sizes and Trends

The Cetacean and Turtle Program (CeTAP) surveys of 1978 through 1982 provided data from which preliminary population estimates of White-sided Dolphins on the New England seaboard have been made (Winn 1982). The peak average abundance, which occurred in the spring, was 36 281± 19 027. The maximum point estimate, after adjustment of sighting effort, was 46 436, although Winn (1982) could not attach confidence limits to this value. The great variability in school sizes (up to 400 animals) influenced the calculation of average population estimates to the point that confidence limits were unrealistically wide. There are no published attempts to estimate numbers of this species in Canadian waters, which lie north of the geographical limit of the CeTAP surveys. No estimates exist for this species in other parts of its range, including the eastern North Atlantic.

Sergeant et al. (1980) concluded, on the basis of non-quantified sighting increases and the occurrence of two mass strandings of White-sided Dolphins in the 1970s, that a real increase in abundance of White-sided Dolphins had taken place in the western North Atlantic. They took no account of great increase in both public and research interest in cetaceans during this period, nor of cetacean-specific surveys in the region during the 1970s, nor of great random factors inherent in mass stranding events. They did not provide convincing data to support reported recent increases in abundance.

Habitat

Surface feeding by this species is not often observed; Winn (1982) reported that only about 6% of the tens of thousands recorded in the CeTAP surveys were engaged in this activity. Winn also reported that most feeding occurred in the vicinity of the 100 m contour in the Great South Channel-Jeffrey's Ledge region. In the course of observing hundreds of White-sided Dolphins in the lower Bay of Fundy between 1985 and 1989, neither the author, L. D. Murison (Grand Manan Whale and Seabird Research Station, North Head, New Brunswick; personal communication) nor T. Woodley (Department of Zoology, University of Guelph, Ontario; personal communication) have noted much obvious surface feeding.

The relationships between the seasonal distribution of the White-sided Dolphin in the western North Atlantic and the major parameters of the physical environment have been assessed by Winn (1982) and Selzer and Payne (1988). The latter determined that 63% of all sightings were made over areas of steepest topographic sea floor relief, and that none were made in shelf areas with minimum relief. They were almost always concentrated over the coastal waters of the inner region of the coastal shelf. Winn (1982) reported sightings over a range of depths from 12 to 2400 m, but calculated that the average depth for all sightings was only 165 m. The maximum surface temperature recorded by Winn (1982) in the presence of White-sided Dolphins was 23.8°C, and the minimum 1.3°C, although 90% were found within a range of 6.0 to 19.9°C, with a mode at 8°C and a mean of 12.8°C. Seltzer and Payne (1988) found somewhat lower values, possibly due to the two samples having unequal seasonal proportionment. In comparison to Winn's (1982) results from the CeTAP surveys, Selzer and Payne (1988) found a range of 1.0 to 13.2°C and an average of 7.0 ± 2.9°C; salinity ranges of 31 to 33‰ were similar.

The diet of White-sided Dolphins varies by region and season, but not always predictably. Sand Lance, *Ammodytes americanus*, has been assumed to be a major item of diet in the Cape Cod area in the spring, when large numbers of White-sided Dolphins gather (Winn 1982; Seltzer and Payne 1988), but this has not been confirmed by stomach content analysis. One problem with this supposition is that *Ammodytes americanus* is most commonly recorded in waters 6 to 20 m deep (Meyer et al. 1979), while the great majority of White-sided Dolphins generally occur over much deeper water. The closely related Northern Sand Lance, *Ammodytes dubius*, is distributed in deeper water, 73-90 m (Scott 1982). If Sand Lance are indeed major prey of White-sided Dolphins, *Ammodytes dubius* may be the species they are taking. Other reported foods include Common Squid, *Ilex illecebrosus*; herring, *Clupea harengus*; and Silver Hake, *Merluccius bilinearis* (Schevill 1956; Katona et al. 1978; Sergeant et al. 1980).

The diet of these animals in the eastern North Atlantic has not been extensively investigated, but appears to include similar species, with the addition of Blue Whiting, *Micromesistius poutassou*, according to Evans (1980), to those listed above.

Habitat Protection

Specific protection of habitat zones for this species would be difficult, given its wide distribution over coastal shelf regions of the North Atlantic. On both sides of the ocean its ranges are criss-crossed by major coastal shipping lanes. Because the White-sided Dolphin is fast and agile, mortality resulting from collisions with ships is probably negligible. The possible impact on the species of crude oil dumped by ships cleaning tanks out of sight of land cannot be measured at this time. Undoubtedly the most obvious current threat to the species is the continued deployment of monofilament gill nets in coastal shelf waters by fishing industries of the United States, Canada, and the nations of western Europe. In the future however, development of western North Atlantic oil fields, such as Hibernia, may pose a much more significant long-range threat to this species.

In recent years concern has grown that competition for food fish stocks between marine mammals and man could be detrimental to populations of these animals. This could be particularly serious when the competition takes place in regions where migrating marine mammals normally rely on concentrations of prey so that they can build up reserves to complete the rest of the migration. The Gulf of Maine would seem to be one of the most important feeding areas for the White-sided Dolphin on the eastern seaboard of the United States, judging by the findings of the CeTAP surveys (Winn 1982). Current studies on the gill net industry in the Gulf by the National Marine Fisheries Service should shortly provide data on entrapment numbers for this species.

Degree of Specialization and Consequent Vulnerability

As Selzer and Payne (1988) pointed out, the relationship between basic environmental parameters and the distribution of White-sided Dolphins is almost certainly indirect. When certain areas are associated with calving, this is just as likely to be related to the particular requirements of the mother as to those of the calf. Encroachment of human activities on any such area, if identified, should be regarded with concern. The species is not particularly vulnerable to capture by ground fish gill nets set at depths of 50 to 100 m, judging from studies in the Bay of Fundy from 1985 to 1989. Only two White-sided Dolphins were recorded in this period, com-

pared to well over 200 Harbour Porpoises. This may be because the White-sided Dolphin in the coastal western North Atlantic feeds primarily on pelagic schooling fish in the upper part of the euphotic zone. Gadoids however, are believed to play a significant role in the diet of the species in British waters (Evans 1980), although estimates for gill net mortality in this region are not yet available.

Biology

Much remains to be learned about the basic biology of the White-sided Dolphin. Some basic life history parameters have been elucidated, largely as a result of the fortuitous examination of two large schools stranded on the eastern seaboard of North America during the 1970s (Geraci et al. 1976; Sergeant et al. 1980; Katona et al. 1983).

Reproductive Biology

Sergeant et al. (1980) summarized their findings based on examination of 65 White-sided Dolphins from the above schools and a number of singly stranded animals. The schools yielded the most information on reproductive parameters because of the large proportion of females (46 of 56), many also pregnant or lactating. Sexual maturity was found to be attained at body lengths of 201 to 222 cm, at six to eight years of age in the female. The numbers of corpora albicantia in the ovaries (including a corpus luteum, if present), ranged from one to 27. Sergeant et al. (1980) were able to use data from the two schools to plot a graph of approximate foetal growth rate. Those foetuses obtained from the September stranding on the coast of Maine had an average length of 4.5 cm (1.8 to 7.0 cm), while those from the May stranding in the Cape Code region averaged 103 cm (83.5 to 113.5 cm). In comparison with a 109 cm neonate recorded by Fraser (1934) at Orkney, north of Scotland in the month of July, most of the foetuses in the Cape Cod stranding must have been near full-term. On the basis of the recorded sizes and the estimated growth curve, the peak of births off the northeast United States is in June and July, with a spread from May to early August. The gestation period was calculated to be close to 11 months (Sergeant et al. 1980). Because of the ratio of pregnant to lactating females in the schools, the same authors postulated a lactation period of 18 months. Since no simultaneously pregnant and lactating females were recorded from the sampled schools, Sergeant et al. (1980) concluded that the reproductive cycle was about 2.5 years in length.

Sexual maturity in the males examined occurred at body lengths of 210 to 244 cm (Sergeant et al. 1980: Figure 4) and at a minimum age of about eight to nine years. The difference in testis weights between mature and immature males was more than one order of magnitude (180 to 370 g compared to 1 to 15 g) respectively. Sperm was present in the epididymis of the mature specimens, but this could be absent from mature specimens at some times of year if there is a seasonal sexual cycle in the male, as was demonstrated for the Harbour Porpoise *Phocoena phocoena* by Gaskin et al. (1984). The oldest specimen in the sample studied by Sergeant et al. was a female estimated to be 27 years of age.

Winn (1982) plotted the distribution of calves in the western North Atlantic population. Mothers with calves were regularly found off Cape Cod and may have been feeding on Sand Lance during spring and early summer when schools of these small fish are at their maximum concentration. By late summer and early autumn calves are commonly found in schools off the southern and eastern coasts of Nova Scotia and in the lower Bay of Fundy (unpublished observations of L. D. Murison, T. Woodley and the author). There are no data on apparent shifts in distribution of the nursing component in other regions.

Movements

Northwestern Atlantic: Winn (1982) discussed seasonal changes in abundance of White-sided Dolphins in the Chesapeake Bay–Gulf of Maine region during the CeTAP surveys of 1978 to 1982. When corrections were made for sighting effort, the abundance was shown to be significantly lower in late fall and winter than in spring and summer. Because there was no evidence of a redistribution southward, or a southward extension of range in the winter, Winn speculated that a seasonal onshore-offshore migration might exist, perhaps following prey movements. This could not be tested during the CeTAP program, since the survey areas were limited under the terms of the original contract. The data could equally support an interpretation of two different populations. Selzer and Payne (1988) noted seasonal changes within the Gulf of Maine, with a marked concentration in the southwestern region in the spring, but dispersal throughout the Gulf in the fall. They related these movements to the seasonal abundance of the presumed major prey species (*see* Habitat section).

Some data are also available for the Bay of Fundy for the period 1980 to 1989, and both short-term and long-term trends can be recognized. From late July until late August, most sightings were concentrated in the NW sector of the central lower Bay. In late August and early September all sightings were made further east and south, in a broad belt running across the middle of the lower Bay from NE to SW and in the last phase of observations, mid-September, almost all sightings were from the eastern half of the Bay. These seasonal changes in distribution are probably related to changes in fish distributions. Data could not be collected later than periods given above because of bad weather. There is some evi-

dence that White-sided Dolphins have become more abundant in the lower Bay of Fundy during the 1980s. Kraus and Prescott (1981) recorded White-sided Dolphins in the upper Gulf of Maine but none inside the Bay of Fundy proper. Analysis of data collected by the Ocean Search whale-watching company gave a strong indication that more White-sided Dolphins were in the Bay of Fundy in 1984 to 1989 than in 1980-1983 (Gaskin, Murison and Woodley, unpublished data).

Northeastern Atlantic: Movements of the species in British waters were discussed by Fraser (1974) and Evans (1980, 1987). Data from this region are based on a mixture of sighting and stranding records and are difficult to interpret, but Evans concluded from recent sighting results that there was good evidence of a northward movement from the North Sea (east of the Shetland and Orkney Islands) in late autumn. Older stranding data, on the other hand, appear to show two peaks (Fraser 1974), one in the northeast of Britain in July-September and possibly another further south. Evans (1980) concluded that these peaks were probably spurious, because strandings are under-reported in the thinly inhabited regions of eastern coastal Scotland and N.E. England. Evans (1980) reported late summer and autumn aggregations of up to about 1000 animals in the northern North Sea; the observations made on these groups suggested that the phenomenon was more likely to be associated with migration than with feeding or reproduction. The presence of such large aggregations of White-sided Dolphins had been previously recorded near the Outer Hebrides (Evans 1980). Sergeant and Fisher (1957) reported a similar aggregation northeast of Cape Freels, Newfoundland in early October 1953, but the possibility that these might have been *Lagenorhynchus albirostris* could not be excluded.

Behavioural Adaptability

Judging from the data accumulated by Winn (1982) and Evans (1980), it seems likely that White-sided Dolphins split up into small groups while feeding, and these merge into larger, sometimes very large, groups while migrating. The distribution in the spring and summer appear related to the availability of an abundant, and possibly highly specific food supply, e.g. Sand Lance in the spring. Both Evans (1982) and Winn (1982) noted that White-sided Dolphins are often seen in company with Fin Whales, *Balaenoptera physalus*; but it is not known if there is a commensal relationship to this or whether it just implies that both exploit the same dense food resources. While the number of different food items recorded from the stomachs of this species is considerable, not all seem to be commonly eaten and some are probably incidental. Furthermore, not all are abundant in any particular region in any given season. It seems unlikely that White-sided Dolphins would display as much feeding adaptability in the face of increased competition for prey species or environmental changes as an inshore euryphagous species such as *Tursiops truncatus*, because they rarely utilize waters close to shore, and frequently become stranded when they do (Geraci et al. 1976). The White-sided Dolphin, largely confined to areas of the coastal shelf where abundant schooling fish or squid occur, will always be vulnerable to increased human impact on its food sources, or large-scale natural fluctuations in food supply.

Limiting Factors

So little is really known about this species that any discussion of limiting factors that might regulate natural population sizes, or present a threat (other than that of incidental capture in fishing gear) is conjectural. The coastal shelf zone inhabited by the species in the North Atlantic is vast, although the prime areas for feeding, at least in the western North Atlantic, appear to be much more limited in extent; e.g., the southwestern Gulf of Maine. Nevertheless, systematic surveys from southern Nova Scotia to the Newfoundland Banks and beyond, may yet reveal other areas of significant concentration. Parasitic infestations and viral, fungal and bacterial diseases are the most likely agents controlling natural population size in species of this kind. An important indirect threat to the continued existence of large populations of the White-sided Dolphin might be increasing competition with fishing industries for its staple prey species of fish and squid. The danger posed by pelagic near-surface drift nets and fixed groundfish gill nets to many small cetaceans does not seem to be a serious problem in the case of the White-sided Dolphin at present. The less obvious threat of hydrocarbon contamination will increase as oil resources on the coastal shelf are developed.

Special Significance of the Species

The White-sided Dolphin is probably the most common small cetacean in shelf waters of the North Atlantic, especially since populations of the Harbour Porpoise, *Phocoena phocoena*, are now in serious decline (Gaskin 1984, 1990). That species is particularly vulnerable to gill net entrapment. The possibility that the White-sided Dolphin may be moving into areas previously occupied largely by Harbour Porpoises is another aspect that needs examination. The ranges of the two species overlap but that of the White-sided Dolphin tends to be further offshore in most areas, concentrating especially in the vicinity of the 100 m depth contour. Because of its exuberant behaviour, the White-sided Dolphin is more often noticed by mariners than the Harbour Porpoise, which rarely bow-rides. From estimates of its rela-

tive abundance and the pollutant loads of specimens taken incidentally in fishing gear, it may provide us with some means of monitoring the ecological "health", of the upper trophic levels of the food web over the middle and outer shelves of eastern North America and western Europe.

Evaluation

While a small number of White-sided Dolphins are killed in fishing gear each year, particularly gill nets, the majority of known mortalities during the last decade have been the result of naturally occurring mass strandings, involving from tens to more than a hundred animals at one time. Because mass strandings of delphinids have been known since antiquity we can presume that in normal conditions such losses are part of the usual stochastic fluctuations of population size and are not a serious threat to the long-term survival of this species in the North Atlantic.

The population size of the White-sided Dolphin in Canadian northwest Atlantic waters is unknown, and likely to remain so in the absence of a major dedicated research program. On the basis of the most northerly CeTAP data collected in the early 1980s, and casual records from Canadian waters, the population of the whole shelf must be at least of the order of the high tens of thousands. There is currently no evidence of any major threat to this species in zones under Canadian jurisdiction.

Potential Trade Threats

Mitchell (1975) summarized former sporadic use of the White-sided Dolphin as a source of meat and oil in Norway. At this time there appear to be no immediate or potential trade threats to this species.

Acknowledgments

I thank L. D. Murison, Manager of the Grand Manan Whale and Seabird Research Station, and T. Woodley of the Department of Zoology, University of Guelph, for collecting data on this species during their survey work in our programs in the lower Bay of Fundy between 1983 and 1989, and R. R. Campbell of the Department of Fisheries and Oceans, Ottawa, and four anonymous reviewers for reading the draft and providing valuable constructive comments that have helped to improve the manuscript. Financial support for the production of this report was made possible through World Wildlife Fund (Canada) and the Department of Fisheries and Oceans.

Literature Cited

Beatty, T. 1989. Whales of the Bay of Fundy. Sunbury Shores Arts and Nature Centre, St. Andrews, New Brunswick.

Bierman, W. H., and **E. J. Slijper.** 1947. Remarks upon the species of the genus *Lagenorhynchus*. I. Proceedings Koniklijke Nederlandse akademie van Wetenschappen 50: 1353–1364.

Bierman, W. H., and **E. J. Slijper.** 1948. Remarks on the genus *Lagenorhynchus*. II. Proceedings Koniklijke Nederlandse akademie van wetenschappen 51: 127–133.

Brown, R. 1868. Notes on the history and geographical relations of the Cetacea frequenting Davis Strait and Baffin's Bay. Proceedings of the Zoological Society of London 1868. Pages 533–556.

Casinos, A., and **J.-R. Vericad.** 1976. The cetaceans of the Spanish coasts: a survey. Mammalia 40: 267–289.

Duguy, R. 1983. Les cétacés des côtes de France. Annales de la Société des sciences naturelles de Charente-Maritime, Supplement 1–112.

Evans, P. G. H. 1980. Cetaceans in British waters. Mammal Review 10: 1–52.

Evans, P. G. H. 1982. Associations between seabirds and cetaceans: a review. Mammal Review 12: 187–206.

Evans, P. G. H. 1987. The natural history of whales and dolphins. Facts on File Publications, New York and Oxford.

Fraser, F. C. 1934. Report on Cetacea stranded on the British Coasts from 1927 to 1932. 11. British Museum (Natural History) London.

Fraser, F. C. 1946. Report on Cetacea stranded on the British coasts from 1933 to 1937. 12. British Museum (Natural History) London.

Fraser, F. C. 1953. On Cetacea stranded on the British coasts from 1938 to 1947. 13. British Museum (Natural History) London.

Fraser, F. C. 1966. Comments on the Delphinoidea. Pages 7-30 *in* Whales, dolphins and porpoises. *Edited by* K. S. Norris. University of California Press, Los Angeles, California.

Fraser, F. C. 1974. Report on Cetacea stranded on the British coasts from 1948 to 1966. 14. British Museum (Natural History) London.

Gaskin, D. E. 1983. The Marine Mammal Community. *In* Marine and Coastal Systems of the Quoddy Region, New Brunswick. *Edited by* M. L. H. Thomas). Canadian Special Publications in Fisheries and Aquatic Sciences 64: 245–268.

Gaskin, D. E. 1984. The harbour porpoise *Phocoena phocoena* (L.): Regional populations, status and information on direct and indirect catches. Report of the International Whaling Commission 34: 569–586.

Gaskin, D. E. 1985. The ecology of whales and dolphins. Heinemann Educational Books, London and Exeter.

Gaskin, D. E. 1992. The status of the Harbour Porpoise, *Phocoena phocoena*, in Canada. Canadian Field-Naturalist 106(1): 000–000.

Gaskin, D. E., G. J. D. Smith, A. P., Watson, W. Y. Yasui, and **D. B. Yurick.** 1984. Reproduction in the porpoises (Phocoenidae): Implications for management. Report of the International Whaling Commission Special Issue 6: 135–148.

Geraci, J. R., S. A. Testaverde, D. J. St. Aubin, and **T. H. Loop.** 1976. A mass stranding of the Atlantic white-sided dolphin, *Lagenorhynchus acutus*: A study into pathobiology and life history. A report on contract MMC-47 submitted in the Marine Mammal Commission by the New England Aquarium, Boston, Massachusetts.

Gray, J. E. 1866. Catalogue of seals and whales in the British Museum. Taylor and Francis, London (Second edition).

Harmer, S. F. 1927 [1914-1927]. Reports on Cetacea stranded on the British coasts, 1-10. British Museum (Natural History) London.

Hellou, J., G. B. Stenson, and **J. F. Payne.** 1989. *Abstract.* Hydrocarbon levels in marine mammals from Newfoundland. Eighth Biennial Conference on the Biology of Marine Mammals, Pacific Grove, California, December 7-11, 1989. Page 27.

Hjort, J. 1902. Fiskeri og hvalfangst i det nordlige Norge. Bergen, Norway.

Jensen, A. 1928. The fauna of Greenland. 1. Mammals. Pages 319-337 *in* Greenland, Volume 1. Reitzel, Copenhagen.

Jonsgaard, A. Aa. 1962. On the species of dolphins found on the coast of northern Norway and in adjacent waters. Norsk Hvalfangsttidende 51: 1–12.

Jonsgaard, Aa., and **O. Nordli.** 1952. Concerning a catch of white-sided dolphins (*Lagenorhynchus acutus*) on the west coast of Norway, Winter 1952. Norsk Hvalfangsttidende 41: 229–232.

Katona, S. K., V. Rough, and **D. T. Richardson.** 1983. A field guide to the whales, porpoises and seals of the Gulf of Maine and eastern Canada — Cape Cod to Newfoundland. Scribner's Sons, New York.

Katona, S. K., S. A. Testaverde, and **B. Barr.** 1978. Observations on a white-sided dolphin, *Lagenorhynchus acutus*, probably killed in gill nets in the Gulf of Maine. United States Fishery Bulletin 76: 475–476.

Kraus, S. D., and **J. H. Prescott.** 1981. Distribution, abundance and notes on the large cetaceans of the Bay of Fundy, summer and fall 1980. Final Report to U.S. Department of Commerce, National Marine Fisheries Service, on contract NA-80-FA.00048.

Lear, W. H., and **O. Christensen.** 1975. By-catches of harbour porpoise *P. phocoena* in salmon driftnets at West Greenland in 1972. Journal of the Fisheries Research Board of Canada 32: 1223–1228.

Leatherwood, S., D. K. Caldwell, and **H. E. Winn.** 1976. Whales, dolphins and porpoises of the western North Atlantic: A guide to their identification. National Marine Fisheries Service Tech. Rep. CIRC-396, Seattle, Washington.

Mercer, M. C. 1973. Observations on distribution and intraspecific variation in pigmentation patterns of odontocete Cetacea in the Western North Atlantic. Journal of the Fisheries Research Board of Canada 30: 1111–1130.

Meyer, T. L., R. A. Couper, and **R. W. Langton.** 1979. Relative abundance, behaviour and food habits of the American sand lance, *Ammodytes americanus* from the Gulf of Maine. United States Fishery Bulletin 77: 243–253.

Mitchell, E. 1975. Porpoise, dolphin and small whale fisheries of the World, status and problems. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland, Monograph Number 3.

Saemundsson, B. 1939. Mammalia. Zoology of Iceland. Rekjavik, Iceland.

Schevill, W. E. 1956. *Lagenorhynchus acutus* off Cape Cod. Journal of Mammalogy 37: 128–129.

Scott, J. S. 1982. Depth, temperature and salinity preferences of common fishes of the Scotian Shelf. Journal of Northwest Atlantic Fisheries Science 3: 29–39.

Selzer, L. A., and **P. M. Payne.** 1988. The distribution of white-sided (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States. Marine Mammal Science 4: 141–155.

Sergeant, D. E., and **H. D. Fisher.** 1957. The smaller Cetacea of eastern Canadian waters. Journal of the Fisheries Research Board of Canada 14: 83–115.

Sergeant, D. E., A. W. Mansfield, and **B. Beck.** 1970. Inshore records of Cetacea for eastern Canada, 1949-68. Journal of the Fisheries Research Board of Canada 27: 1903–1915.

Sergeant, D. E., D. J. St. Aubin, and **J. R. Geraci.** 1980. Life history and northwest Atlantic status of the Atlantic white-sided dolphin, *Lagenorhynchus acutus*. Cetology 37: 1–12.

Sigurjonsson, J., and **T. Gunnlaugsson.** 1988. Distribution and abundance of cetaceans in Icelandic and adjacent waters from sightings surveys conducted in June-July 1987. Conseil international pour l'exploration de la Mer. Charlottenlund Slot, Denmark, document 1988/ Number 14.

Stenson, G. B., and **D. G. Reddin.** 1989. *Abstract.* Incidental catch of marine mammals and birds in an experimental salmon drift net fishery. Eighth Biennial Conference on the Biology of Marine Mammals, Pacific Grove, California, December 7-11, 1989. Page 65.

Stenson, G. B., and **D. G. Reddin.** 1990. Incidental catches of small cetaceans in drift nets during salmon tagging experiments in the Northwest Atlantic. Page 46 *in* IWC Symposium on Mortality of Cetaceans in Passive Fishing Nets and Traps. La Jolla, California, October 20-21, 1990.

Toschi, A. 1965. Fauna d'Italia. Mammalia: Lagomorpha, Rodentia, Carnivora, Ungulata, Cetacea. Bologna.

Utrecht, W. L., van, and **A. M. Husson.** 1968. Strandingen van Cetacea in her voor jar van 1967 op de Nederlandse kusten. Lutra 10: 7–17.

Viale-Pichod, D. 1977. Écologie des cétacés en Méditerranée nord-occidentale: leur place dans l'écosystems, leur réaction à la pollution marine par les metaux. Thèse de doctorat d'état es sciences naturelles, a l'université Pierre et Marie Curie (Paris VI).

Watson, L. 1981. Sea guide to whales of the world. Nelson Canada Limited, Scarborough, Ontario, Canada.

Winn, H. E. 1982. A characterization of marine mammals and turtles in the mid and North Atlantic areas of the U.S. Outer Continental Shelf. Final Report of Cetacean and Turtle Assessment Program (CeTAP), contract No. AA551-CT8-48 to the Bureau of Land Management, U.S. Department of the Interior, Washington, D.C.

Accepted 31 May 1991

The Extent, Floristic Composition and Maintenance of the Rice Lake Plains, Ontario, Based on Historical Records

P. M. Catling[1], V. R. Catling[1] and S. M. McKay-Kuja[2]

[1]8 Scrivens Drive, R.R. 3, Metcalfe, Ontario K0A 2P0
[2]133 Oakes Drive, Mississauga, Ontario L5G 3M2

Catling, P. M., V. R. Catling, and S. M. McKay-Kuja. 1992. The extent, floristic composition and maintenance of the Rice Lake Plains, Ontario, based on historical records. Canadian Field-Naturalist 106(1): 73–86.

In order to: (1) contribute to the development of a conservation strategy for prairie and savanna in central Ontario, (2) contribute to an understanding of natural vegetation patterns, and (3) provide a basis of historical documentation for work on prairie and savanna remnants, we gathered and synthesized data concerning the Rice Lake Plains from original surveys, pioneer diaries and from early publications of botanists Catharine Parr Traill and John Macoun. The Rice Lake Plains, north of central Lake Ontario, was an extensive, continuous prairie and savanna extending over an area of at least 172 km^2 (66 square miles) and possibly as much as 250 - 300 km^2 (96 - 111 square miles). It was dominated by prairie grasses and included many other characteristic prairie and open ground species that are now rare or restricted in Ontario. Its flora represents a particular kind of prairie and savanna that occurred in the central region of southern Ontario, and the existing remnants are representative, based on the historical record. This prairie and savanna was probably maintained by a combination of edaphic factors, and both natural fires and fires caused by Indians, and was a large patch of prairie and savanna within a much larger region, corresponding approximately to the eastern portion of the Oak Ridges moraine, that included many similar, but probably smaller, patches. This region north of Lake Ontario is the northeastern limit of extensive prairie and savanna vegetation.

Key Words: Prairie, savanna, vegetation, Rice Lake, Ontario, Great Lakes region, phytogeography, Catharine Parr Traill, John Macoun.

Prairie and savanna vegetation (*sensu* Curtis 1959), frequently called "plains" by the early explorers, existed far to the east of the prairie peninsula (*sensu* Transeau 1935), and discontinuously throughout much of southern Ontario (Figure 1) and even on the Atlantic coast (e.g., Day 1953). In the Carolinian zone of Ontario, prairie vegetation existed at points along the Detroit, St. Clair, Thames and Grand Rivers, on the Walsingham Sand Plain, and on dunes along the shores of lakes Erie, Huron and Ontario (e.g., Alison 1976; Bakowsky 1988; Faber-Langendoen 1984; Faber-Langendoen and Maycock 1987; Langendoen and Maycock 1983; Lumsden 1966; Pratt 1979; Rogers 1966; Szeicz and MacDonald 1991; Wood 1961). Although a fully reliable indication of the extent of these prairies in southwestern Ontario is not currently available, there is reason to believe that some of them extended far beyond the areas covered by dots in Figure 1 (e.g., Lumsden 1966; Szeicz and MacDonald 1991; Wood 1961). Prairie vegetation has also been well documented further to the east in the Lake Simcoe area (Reznicek 1980, 1983; Reznicek and Maycock 1983) and at the western end of Lake Ontario (Varga 1989). It is less widely known that extensive areas of prairie and savanna existed in New York State south of Lake Ontario (Day 1953), and also 12 km to the north of central Lake Ontario (e.g., Traill 1836). The large prairie north of Lake Ontario, called the "Rice Lake Plains", was well documented by botanists Catharine Parr Traill (1868, 1885) and John Macoun (1883, 1884, 1886a, 1886b, 1888, 1890a, 1890b) as well as by the early surveyors and travellers.

Here we bring together historical evidence for the size of the Rice Lake Plains and consider its composition and maintenance based on early published observations. This work was done in order to: (1) contribute to the development of a conservation strategy for prairie and savanna in central Ontario by placing existing remnants within the context of presettlement vegetation, (2) contribute to an understanding of the natural vegetation patterns of the southern Great Lakes region, and (3) provide a basis of historical documentation for additional work by the authors that is currently underway on prairie and savanna remnants in the central portion of southern Ontario. The Rice Lake Plains are at the northeastern limit of extensive prairie and Black Oak savanna vegetation in North America (Figure 1), thus making their historical documentation of particular interest in terms of ecology and phytogeography.

Methods

Original surveys that existed for townships on the south side of Rice Lake were checked at the Ontario Ministry of Natural Resources, Information Branch, Survey Records Section, for reference to plains and treeless areas. The Northumberland soil survey (Hoffman and Acton 1974) was used along with the Rice Lake topographic map (Energy, Mines and

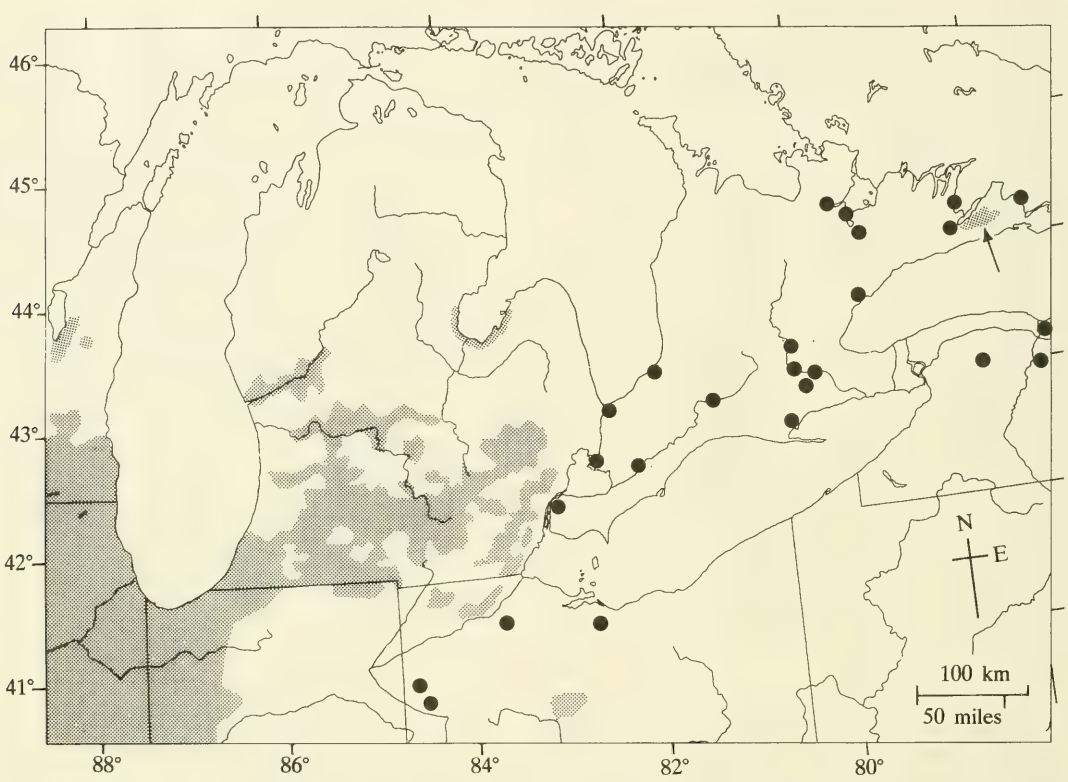


FIGURE 1. The extent of prairie and Oak savanna in the eastern Great Lakes region in presettlement times. Both shading and dots represent the same; i.e., prairie or savanna or both. The position of the Rice Lake Plains near to the northeastern limit of prairie and savanna is shown with an arrow. Based on Transeau (1935), Nuzzo (1986), a map of the natural vegetation of Ohio (Ohio Department of Natural Resources), Day (1953) for New York, and personal observations as well as references cited in the text for Ontario. No attempt here is made to separate prairie and savanna because over much of the area it cannot be done reliably on the basis of the presettlement data. However, much of the area south and west of Lake Michigan was prairie, whereas much of the area in Michigan was Oak savanna and Oak woodland with prairie glades.

Resources Canada, 31 C/4, 1:50 000) to determine the likely extent of prairie. Publications and diaries of early travellers and botanists were checked for references to the Rice Lake Plains, including particularly the works of Catharine Parr Traill (1836, 1868, 1885) and John Macoun's catalogue (1883, 1884, 1886a, 1886b, 1888, 1890a, 1890b). The National Archives and Queens University Archives were also checked for any relevant unpublished information gathered by early botanists including John Macoun and Catharine Parr Traill.

Early Descriptions of the Rice Lake Plains

On 1 September 1832, about halfway between Cobourg and Rice Lake, Catharine Parr Traill ascended the Rice Lake Plains above the hamlet of Cold Springs, which is still so named today. Her published letter 5 (Traill 1836) describes the plains: "We now ascend the plains — a fine elevation of land — for many miles scantily clothed with oaks, and here and there bushy pines, with other trees and shrubs. ... With trees growing in groups, or singly, at considerable intervals, giving a sort of park-like appearance to this portion of the country". Other passages refer to oak brush (Traill 1885, page 179) with "large timber trees here and there" and to "grassy plains", "extensive grassy flats" and "open tracts of land". Traill's books contain many references to "plain-lands" which seems odd to present-day field biologists in southern Ontario who think mostly in terms of vast forests in presettlement times. Her *Studies of plant life in Canada* (Trail 1885) has the alternate title "Gleanings from forest, lake and plain". It is clear that she was strongly influenced by the splendour and the extent of the Rice Lake Plains.

Several early surveyors also noted largely treeless areas that they referred to as "plains" or "the Rice Lake Plains" on the south side of Rice Lake. It is evident from detailed descriptions of some of these sur-

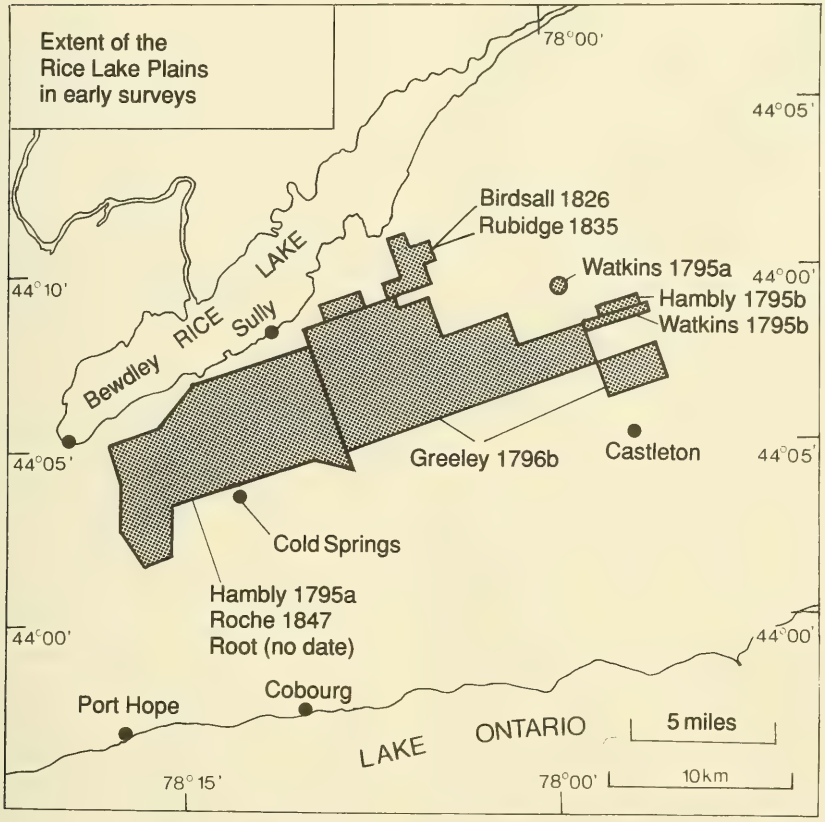


FIGURE 2. Extent of the Rice Lake Plains based on early surveys.

veyors and Traill (above) that all of the early references to plains referred to naturally treeless areas. For example, John Smith (1827), the deputy provincial surveyor, noted: "very extensive ridges border Rice Lake, which from their being bare of timber are called the Rice Lake Plains." Traill (1885) made "plains" and "prairies" equivalent in reference to lupine: "Those who know the Blue Lupine only as a cultivated flower can form but a poor idea of its beauty in its wild state on the rolling prairies or plainlands."

The Definition of Prairie and Savanna

Considering the spacing and size of trees suggested by the various descriptions (see above and below), and especially the references to "no timber or even bushes" and "trees a quarter of a mile apart" and "open plains", we conclude that much of the Rice Lake Plains was a prairie with less than one mature tree per acre. This is further supported by its floristic composition (see below). Areas of savanna, where tree cover exceeded one tree per acre but with the canopy more than 50% open, also existed, based on references to "oak brush" and "parkland". The savanna communities evidently included both open savanna and scrub savanna (*sensu* Bray 1955, 1960). There were apparently also groves or small patches of woodland, where the canopy was less than 50% open. These definitions of prairie, savanna and woodland follow Curtis (1959). Although it is desirable to define the use of these terms here, the fact remains that a widely accepted concept of savanna has been elusive (e.g., Nuzzo 1986)[1].

Extent of the Rice Lake Plains

Early surveys

The earliest survey on the south side of Rice Lake was that of William Hambly (1795a) for Hamilton Township (Figure 2). He found that "the extra conces-

[1]However, savanna is a recognizable community type, despite the problems of delineation, since it not only combines prairie and woodland elements, but is also a habitat where some species reach their maximum abundance. Packard (1991) recently made a valuable contribution to our understanding of savanna.

sion of this township and the five first concessions are a good soil, well timbered and to appearance well watered, the residue [concessions 6-9] bushy or burnt plains" and often "the land having no timber or even bushes." He found the east line of the township "legible to the 8th concession, then plains". In 1847, J. K. Roche resurveyed Hamilton Township and described the 7th concession line as passing "through tracts of oak plains where the timber is very much scattered, trees bearing marks on them being sometimes as much as a quarter of a mile apart." He noted that concession 8 runs "chiefly through a tract of oak plains which have been generally on fire during the summer months." Within an area of approximately 83.6 km^2 (33.2 square miles), all of his reference points at varying chain lengths across the townships, as well the reports of Root (undated), refer to plains as "open plains", "open plains, a few scattered oaks", "oak plains", or "open plains pine and oak."

In 1795 Seth Watkins surveyed the perimeter of Haldimand Township (Watkins 1795a) and described the the west line along the 8th and 9th concessions as "shrub oak bushy plain" and the upper part of concession 9 was partially a "pine plain." Plains were also described on the east boundary (Figure 2). In a more thorough survey of the township conducted a year later, Aaron Greeley (1796b) found that "the whole of the 7th concession is on what are called the Rice Lake Plains and is principally covered with oak and pine bushes, with now and then a large oak or pine. The soil is a light black sand and appears to be excellent wheat land, it is destitute of water." The extent of the plains in Haldimand as noted by Greeley was approximately 71.6 km^2 (27.6 square miles).

Richard Birdsall surveyed portions of Alnwick Township in 1826. In various lots he records "plains thinly timbered with oak and pine" and "open plains." Alnwick was later surveyed by Frederick Preston Rubidge in 1835. Adding his "plains" to those of Birdsall, the total extent of reported plains in Alnwick was approximately 7 km^2 (2.7 square miles).

Greeley (1796b) reported 6.7 km^2 of plains in Cramahe Township representing the easternmost extent of the plains in Figure 1. Watkins (1795b) reported "bushy oakland" in the rear of concession 10. In the adjacent lots 5-9 at the front of the first concession of Percy Township, Hambly (1795b) noted "plains, bushes". Based on these reports the area of plains in Cramahe and southern Percy townships was 10 km^2 (3.9 square miles).

Taken together (Figure 2) these surveys describe plains in an area of approximately 172.2 km^2 (66.5 square miles). However, the entire areas of the townships concerned were not described in terms of tree cover. Only a small area of Alnwick, for example, was surveyed. Additionally we outlined the area of Hamilton within which points are described as "plains", by joining the outermost of these points, but undoubtedly there was prairie all around many of the points on our border. Thus the estimate of size of the plains based on early surveys is very conservative and probably too low and therefore should be considered a minimum area.

Linear distances

Although the early surveys are the most accurate indications of extent, several other references are of interest. Both Catharine Parr Traill (1836) and her brother Samuel Strickland (1853) refer to the width of the plains between Cold Springs and Harwood (then called Sully). Strickland writes "It can hardly be imagined what a relief it is to the eye, after travelling for miles through a dense forest, to see such a beautiful landscape suddenly burst on your site. For nearly three miles our road lay through natural park-like scenery, flowery knolls, deep ravines, and oak-crowned hills, with every now and then the blue waters of the lake glittering through the trees". Strickland also noted that the plains "extend for nearly 20 miles along the south shore, forming the rear of the townships of Hamilton and Alnwick".

Extent of dry, sandy soils

There are a number of other ways in which the extent of the plains might be estimated. The present locations of remnant prairie vegetation, and the distribution of Black Oak and prairie grasses may be assumed to approximate the area of prairie. Although a rich undisturbed association of prairie plants is often a reliable indication of formerly widespread prairie within a region, it might be argued that a small presumed remnant hardly proves that prairie was any more extensive than the size of the remnant, and characteristic prairie plants may have spread after forest clearing. Although there is not much evidence for this in Ontario, prairie plants are adventive in some sites (e.g., Catling and McKay 1974). Present occurrences of prairie vegetation and prairie species can be no more than suggestive of the extent of prairie. The great advantage of the historical records is that they are unambiguous. There is one other aspect, though, that should be considered along with the historical data and that is the extent of the soil types that supported prairie on the Rice Lake Plains.

Most southern Ontario prairies occur on sand or coarse till, and not surprisingly the area of the Rice Lake Plains is largely an area of sandy soils. The dryness of the soil was probably an important factor in maintaining the plains, and the higher elevations and areas of coarse, well-drained soils were the most likely to have been plains. The area of mostly sand and sandy loam soils over 800' in elevation is shown in Figure 2. The outline of the plains (Figure 1) cor-

responds well with the distribution of these dry soils. Perhaps as much as 10% of the dry soil area has finer, moist soils in stream valleys etc. Excluding 10%, the surface area is approximately 241 km^2. This area includes an east-west band and an upper and lower arm. Much of the upper and lower arms include a mosaic of loam and sandy loam soil types with Dundonald series loam and sandy loam being prominent. This series has a pH of 6.2 – 6.5 in the upper horizons and is approximately 50% sand throughout (Hoffman and Acton 1974). In contrast the east – west band is characterized by extensive, uniform areas of more coarse (higher sand content) and more acid soils with lower moisture holding capacity. Most of this area is Pontypool series sand or Dundonald series sandy loam. Of these, the latter is less coarse and consequently less dry, but it is also less widespread. All of the aforementioned soil series are definitely to be associated with the plains because they had plains vegetation according to the early surveys and descriptions (see above). The area of essentially uniform Pontypool sand and Dundonald sandy loam shown and the northern arm of Bondhead sandy loam (following Strickland's note on length) on Figure 1 may be interpreted as a minimum extent of the Rice Lake Plains. If the area of Dundonald sandy loam at the northern end of the south arm, which was Pine-Oak forest according to the early surveys, is excluded, and 10% is excluded for river valleys and isolated lowlands, an area of approximately 192 km^2 (74.1 square miles) is obtained. However, this is undoubtedly too small because the early surveys indicate prairies existing below 800' and outside of the shaded areas in Figure 2. The area of reported presettlement plains (Figure 1) outside of the shaded portions of Figure 2 amounts to 56.2 km^2 (21.7 square miles). The larger isolated area of 8 km^2 (3 square miles) on the right-hand side of Figure 2 contains remnants strongly suggestive of widespread prairie in that region. However, there is still no adequate indication of prairie in the lower arm of the shaded area in Figure 2 so this must still be excluded. The total area of continuous prairie and savanna considering these additions is approximately 267 km^2, but this is still probably low because prairie remnants currently exist further west. It is therefore not unreasonable to conclude that the Rice Lake Plains probably extended over an area of 250 - 300 km^2 (96 - 111 square miles, 68 524 - 82 230 acres), and may have been even more extensive.

This is a remarkably large area for the predominantly forested region of eastern North America, and it undoubtedly represents one of the largest continuous areas of dry and mesic prairie and savanna vegetation that existed in Ontario at least at the time of settlement.

Extent of the Rice Lake Plains prairie region

A series of smaller natural openings may have extended both east and west of the essentially continuously open area of the Rice Lake Plains. To the east there are currently prairie relicts on both sides of the Trent River near Stirling, some of which were evidently extensive prairies prior to settlement. These are 27 km E of the limits of the Rice Lake Plains as shown in Figure 1, and openings in dry, open Black Oak woods currently exist 15-20 km E of the Rice Lake Plains. Unfortunately, we have no proof that the prairie and savanna extended continuously this far, but it is clear that it was at least discontinuous far to the east of the areas shown in Figures 2 and 3.

There was an Indian trail or "carrying place" on the west side of the Rice Lake Plains (Fothergill 1817; Frost 1973) that extended from Smith's Creek (now Port Hope) to the southwest corner of Rice Lake (at the present site of Bewdley). At the Rice Lake end of this carrying place were plains (Hambly 1795a; Fothergill 1817), but these plains were evidently separated from the Hamilton Plains, as that portion of the Rice Lake Plains in Hamilton Township was called, by deciduous woods. Fothergill (1817) describes the Indian trail: "in some places the forest is open ... It closely resembles the finest park scenery in England." To the west of Rice Lake, there was an area of plains in the 9th and 10th concessions of Hope township where a settler reported to Roche (1845) that "the area burned nearly every summer". Consequently the area within which patches of prairie and savanna vegetation, some quite large, existed prior to settlement in Rice Lake – Trent River area is very extensive. In fact, the Rice Lake Plains was simply the largest continuous patch, in an extensive region of many patches. This region corresponds approximately to the eastern portion of the Oak Ridges moraine, a relatively high area of coarse soils. It extends from Pontypool (or possibly further west) east to east of Stirling, a distance of 90 km (56.2 miles), and an area of at least 450 km^2 (175.8 square miles). Again, an area this large where prairie and savanna was a very prominent feature, is remarkable for this part of the northeast.

The presettlement extent of prairie and savanna in Ontario

Of course, the realization that extensive areas of prairie and savanna existed north of Lake Ontario raises the question of the extent of these communities elsewhere in southern Ontario. While many biologists are aware of prairie and savanna remnants near Windsor and on Walpole Island, and elsewhere a few narrow strips along railway tracks, few have considered their possible extent in presettlement times. There is every indication that they were so extensive that it would require a rather intensive study to document them. For example, Wood (1961) shows 63 km^2 (39.2 square miles) of Oak plains in

Dumfries Township, Brant County. For the larger area of sand deposits extending north of Long Point, Lake Erie (not including Dumfries Township) including parts of the Burford Plains, Sziecz and MacDonald (1991) have recently shown approximately 184 km^2 (71 square miles) of presettlement Oak savanna, and this is evidently a minimum since information is lacking for a part of the area. Lumsden (1966) speculated on the extent of prairie in extreme southwestern Ontario, and although much of the landscape giving rise to the prairie-like soils of that region may have been marsh or wet prairie, there is reason to believe, on the basis of remnants and habitat for the prairie chickens once present, that extensive drier prairies and savannas existed here as well. In pre-Columbian times, prairie and savanna may have been more extensive throughout the northeast, especially during the hypsithermal interval 7000-5000 B.P. (e.g., Schmidt 1938). Prairie and savanna was a major presettlement feature of the southern Ontario landscape; southern Ontario was not all forest, contrary to the broad sweep of large scale vegetation maps.

Floristic Composition

Surveyors

The early surveyors (e.g., Birdsall 1826; Greeley 1796a, 1796b) made reference to areas of pine and oak around the plains, and Roche (1847) made specific reference to White and Black Oak tree markers within the plains of Hamilton township. The pine was probably mostly *Pinus resinosa* since Macoun noted that "the Rice Lake Plains are chiefly covered with this tree" and the early surveyors frequently referred to "Red Pine" or "Yellow Pine". There are also references to "brush", "brushwood", and "scrub-by oak" on the areas adjacent to plains in Alnwick. Poplar was associated with oak and pine around the plains in Alnwick.

Early botanists

CATHARINE PARR TRAILL

Little information on the Rice Lake Plains was found in Catharine Parr Traill's documents in the National Archives, presumably because most of Traill's notes, manuscripts and letters were lost in one or more fires, notably the burning of Oaklands in 1857 (Martin et al. 1986). However, Traill (1885) provided a relatively detailed account of the floristic composition of the Rice Lake Plains in various publications (Table 1). She had access to Pursh's *Flora Americae Septentrionalis* while on the Otonabee (Morris 1966; Needler 1946; Traill 1836). She also corresponded extensively with the prominent botanists of her time, notably the Canadian botanists John Macoun, James Fletcher, and George Lawson, but also botanists in England and the United States (Traill 1836; Morris 1966). These botanists probably assisted her with identifications and she undoubtedly sent specimens to some of them, although her collections from the plains have not been located in a Canadian herbarium (Dore 1966). Some of her collections, possibly including material from the plains, are in the herbarium of the Scottish Natural History Society (ESNHS) now housed in the Natural History Department of the Glasgow Museum (GLAM) in Scotland (Kent and Allen 1984). Botanical scrapbooks made by Traill are at QK, TRT, Trent University, and the Rare Book Room of the University of Toronto, but these do not include plants from the Rice Lake Plains (Dore 1966; Boivin 1980). Traill sold pressed plants in England and possibly some of her specimens are to be found there. She was accurate in her work[2] and all of the plants she reported from the plains (Table 1), with the exception of *Gentianella quinquefolia* (which undoubtedly occurred there at the time), are currently documented by specimens collected by the authors in recently discovered remnants (CAN, DAO). Traill was apparently most concerned with attractive plants, edible plants, and larger important plants. Three of her books (1836, 1868, 1885) are useful in terms of floristic composition of the Rice Lake Plains.

JOHN MACOUN

John Macoun, one of Canada's great field botanists, spent most of 1860 in Castleton, from where he made excursions onto the Rice Lake Plains (Macoun 1922). Reference no. 259 in Adams' (1928) bibliography is Macoun's *List of plants of Northumberland Co., Ontario* published in "Ann. Kingston Bot. Soc." in 1863. However, a search of many libraries and archives failed to produce this publication. At the 26 January 1863 meeting of the "Kingston Botanical Society", Macoun's paper entitled "On the physical character of the East Riding of Northumberland with a list of the plants" was read (Lawson 1863). It was noted that the list contained "about 800 species" and that "it will appear in the annals", but the last issue of the the Annals of the Botanical Society of Canada was published in 1862, its folding evidently being partly due to George Lawson's move from Queens University in Kingston to Halifax (Boivin, personal communication). It

[2]The variety *traillae* of *Dryopteris marginalis* was named by George Lawson in her honour (Edinburgh New Philosophical Journal 19: 275. 1864. Weatherby 1941).

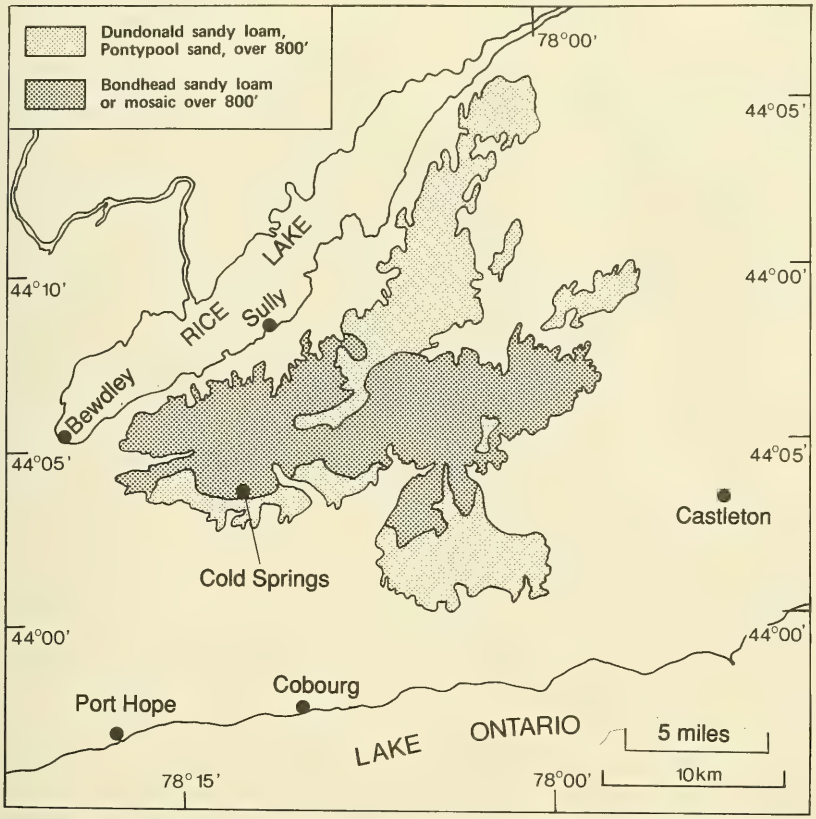


FIGURE 3. Extent of Dundonald sandy loam, Pontypool sand and Bondhead sandy loam in the region south of Rice Lake all over 800' in elevation. After Hoffman and Acton (1974).

seems likely that a group of botanists in Kingston attempted to continue after Lawson left, under the name "Kingston Botanical Society", but there is no record of a meeting after 1864, nor is there any record of their publication of annals. Since the western portion of the Rice Lake Plains is in Northumberland County, and Macoun is known to have visited the plains, his list of Northumberland plants may have been a valuable source of information, but it is doubtful that it was ever published, and it is possible that Adams' (1928) reference to it is based on Lawson's notice of the reading and indication of intent to publish. This possibility would explain why Adams did not provide page numbers. Most of the Macoun material in the National Archives dates after 1881, and the manuscript list was not found in archival materials of other contemporary botanists such as Asa Gray and A. T. Drummond, nor have those who have worked extensively with older botanical literature been able to find it (W. G. Dore, M. Shchepanek, J. H. Soper, W. A. Waiser, personal communications).

Fortunately, Macoun made many references to the Rice Lake Plains in various publications, which although rare, are readily available. His *Catalogue of Canadian plants* (1883, 1884, 1886a, 1886b, 1888, 1890a, 1890b) and to a lesser extent some of his other publications (e.g., Macoun 1876; Macoun and Gibson 1876, 1877) contain scattered references to the Rice Lake Plains. Macoun mostly reported plants that were geographically limited in eastern Ontario. Thus, his reports are complementary to those of Traill. The Geological Survey was initially unwilling to purchase all of Macoun's personal herbarium (Waiser 1989) and a policy of limited collection growth apparently existed until 1892 (Boivin 1980). Consequently Macoun sold some collections (Boivin unpublished) and distributed others as gifts in return for expert identifications, thus explaining the very wide distribution of his material. Undoubtedly, European and U.S. herbaria contain some of his early collections, but we found only a single sheet of *Castilleja coccinea* at CAN to support his early reports from the Rice Lake Plains (Table 1).

TABLE 1. Species reported by Catharine Parr Traill ("T"), John Macoun ("M") and George Lawson ("L") from the Rice Lake Plains. Names preceded by an "h" are reported by Traill from dry, open habitats rather than specifically from the plains, but judging by the title of the book (Traill 1885) they were undoubtedly found on the plains. A "d" indicates species reported by Macoun in an 1867 letter to A. T. Drummond. Common names provided by Traill are given where they help to establish the identity of the plant, otherwise only her scientific names are are listed. Our comments are in parentheses. From Traill (1836, 1868, 1885), Macoun (1867, 1876, 1883, 1884, 1886a, 1886b, 1888, 1890a, 1890b), Macoun and Gibson (1876, 1877) and Lawson (1884).

T	*Amelanchier* sp., Sheep Berry (probably *Amelanchier sanguinea*)
T	*Amelanchier* sp., Dwarf Juneberry (probably *A. alnifolia* var. *compacta* and var. *alnifolia*)
TM	*Andropogon gerardii*
d	*Anemone cylindrica*
L	*Anemone virginiana* (reported as "common on plains at Castleton")
ThM	*Asclepias tuberosa*
M	*Aster ericoides* (reported as *A. multiflorus*)
M	*Aster oolentangiensis* (reported as *A. azureus*)
M	*Aster undulatus* (somewhat doubtful)
M	*Botrychium obliquum* (reported as *B. ternatum* var. *obliquum*)
T	*Calystegia spithamea*
M	*Carex siccata* (frequently treated as *C. foenea*)
TM	*Castilleja coccinea*
M	*Cornus rugosa* (reported as *C. circinata*)
M	*Cyperus lupulinus* (reported as *C. filiculmis*)
T	*Cypripedium pubescens*
M	*Desmodium paniculatum*
M	*Festuca* sp. (probably *F. rubra*, reported as *F. tenella*)
M	*Gentianella crinita* (it is not clear which subspecies is the basis for the report)
T	*Gentianella quinquefolia* — Reported as "Five-flowered Gentian" which at the time was called *Gentiana quinqueflora*, now treated as a synonym of *Gentianella quinquefolia*.
Md	*Helianthemum canadense*
M	*Hypericum pyramidatum*
M	*Lactuca hirsuta*
M	*Lechea minor* (more likely to have been *L. intermedia*)
M	*Lespedeza capitata*
Td	*Liatris cylindracea*
TM	*Lilium philadelphicum*
ThM	*Linum sulcatum*
d	*Linum virginianum* (possibly *L. sulcatum*)
TM	*Lupinus perennis*
M	*Lysimachia quadrifolia*
M	*Orobanche uniflora* (reported as *Aphyllon uniflorum*)
M	*Oryzopsis canadensis*
M	*Panicum xanthophysum*
M	*Pinus resinosa*
Md	*Polygala polygama*
d	*Polygala senega*
T	*Prunus pumila*, Dwarf Cherry, Sand Cherry (evidently this is what we now would call *P. susquehanae*)
M	*Pycnanthemum virginianum* (reported as *P. lanceolatum*)
T	*Pyrola rotundifolia*
T	*Quercus macrocarpa*, Mossy-cup Oak
T	*Quercus* sp., Cray Scrub Oak (probably *Q. alba*)
T	*Quercus* sp., Black Scrub Oak (probably *Q. velutina*)
M	*Ranunculus rhomboideus*
M	*Rhus aromatica*
M	*Rosa carolina* (reported as *R. humilis*)
M	*Rosa virginiana* (Macoun 1876 as *R. lucida*)
T	*Rudbeckia hirta*
T	*Salix* sp., Dwarf Willow (probably *Salix humilis*)
M	*Saxifraga virginiensis* (Macoun 1876)
M	*Schizachyrium scoparium*
M	*Selaginella rupestris*
TM	*Sorghastrum nutans*
d	*Trifolium stoloniferum* (unlikely, not repeated in the Catalogue)
T	*Vaccinium corymbosum*, Swamp Blueberry, Huckleberry
M	*Viola sagittata*

FIGURE 4. Prairie and savanna near Alderville, within the region of the once extensive Rice Lake Plains. The trees are Black Oak (*Quercus velutina*), White Pine (*Pinus strobus*), Red Pine (*Pinus resinosa*) and Paper Birch (*Betula papyrifera*). Taller shrubs and saplings are conspicuously absent due to ground fires. Plants among immature prairie grasses in foreground are Butterfly-weed (*Asclepias tuberosa*), Tall Cinquefoil (*Potentilla arguta*) and Showy Tick-trefoil (*Desmodium canadense*). Among the provincially or regionally rare plants occurring within the area of this photograph were *Asclepias exaltata*, *Carex richardsonii*, *Cirsium discolor*, *Panicum perlongum*, *Panicum praecocius*, *Polygala polygama*, *Ranunculus rhomboideus*, and *Solidago arguta*.

However, most of his reports from the plains are documented by more recent collections by the authors, the exceptions being *Aster undulatus*, *Lechea minor*, *Pycnanthemum virginianum*, *Rosa carolina* and *Trifolium stoloniferum*. Of these, the first two and the last are the most unlikely. Vouchers for these were not found at CAN, DAO, QK, TRT and MTMG (Holmgren, Keuken and Schofield 1981).

Significance of the early botanical observations

The vast majority of species reported by both Traill and Macoun (Table 1) are native species of open habitats that are restricted in their Ontario distributions, and more than half of them are characteristic species of eastern prairie remnants and/or the former midwestern prairie continuum. This list is certainly not complete, but it nevertheless gives a very clear picture of a prairie.

The early botanists understood the phytogeography and relationships of the Rice Lake Plains flora remarkably well. Traill realized that the plains contained plants that were restricted to prairie habitats, but she also knew some of the other prairie habitats where they occurred. She wrote: "A number of exquisite flowers and shrubs adorn these plains, which rival any garden in beauty during the spring and summer months. Many of these plants are peculiar to the plains and are rarely met with in any other situation" (Traill 1836). With respect to *Castilleja coccinea* she wrote that "you would find it in its greatest perfection ... on the high, dry, rolling plains of Rice Lake, Brantford, the Humber, to the north of Toronto, Stoney Lake, the neighbourhood of Peterborough (then called Scott's Plains), and similar localities" (Traill 1885). Macoun (1867) in a letter to A. T. Drummond noted that some of the plants

he found on the sandy soils of Northumberland (several species in Table 1 were listed) were mainly western or southwestern, and that in the region these plants were confined to coarse soils. Drummond (1867) published this observation adding that the southern and western species were present because they required a "higher degree of heat than plants of our eastern districts," this higher level of heat resulting from the openness of the habitat and the tendency for dry substrates to absorb heat.

Anecdotal comments are provided for some of the plants reported. Some were found to be abundant: "the sand cherry abounds on light plain-lands" and "the extensive grassy flats were brilliant with the azure hues of lupine." The "extensive grassy flats" were probably the central portion of the plains in Hamilton Township, one of the few extensive flat areas, but Lupine also occurred far to the west on that portion of the plains near Castleton where Macoun (1883) reported it as common. Traill reported "pidgeons" feeding on the Sand Cherries. These were undoubtedly Passenger Pigeons, which may have been important agents in the dispersal of Sand Cherry. These birds were abundant when she first saw the plains, but their extinction occurred during her lifetime.

Traill (1885) made several references to extensive grassy areas (e.g., above), which along with her identification of the grasses *Andropogon gerardii* and *Sorghastrum nutans* and other information (see above and below), make it quite clear that large portions of the Rice Lake Plains were prairie. Macoun (1888) provides additional support for this noting that *Andropogon gerardii* was "very abundant on Rice Lake Plains" and that *Sorghastrum nutans* was "common", but he added another prairie grass, *Schizachyrium scoparium*, which he reported to be "abundant". Evidently these were the grasses that dominated the plains. There was also Oak scrub where "with difficulty a path can be forced between the stems" (Traill 1885). There was also what may be called savanna (see descriptions and definition above) where the trees were closer. However, there was no clear indication of sand barrens or heath barrens.

One is naturally led to wonder why McAndrews (1984) did not find evidence of the great prairie in his Rice Lake cores. Among the possible explanations is the fact that the core sites were on the north side of the lake and downwind from the north shore, which was probably always largely forested.

Representivity

Remnants of the Rice Lake Plains recently discovered by the authors include most of the species recorded by Traill and Macoun (Table 1), and some other interesting species of open ground, but not a great many more than were reported by these early botanists. This suggests that our knowledge of the floristic composition of the Rice Lake Plains is fairly complete and species representivity (*see* Catling and Hélie 1990) is high, i.e., the remnants are representative of the previously existing ecosystem in terms of plant species composition. Undoubtedly, the prairies and savannas of this area contained plants that we have neither current nor historic records of, but they are probably few in number and they are probably largely those species known from prairies and savannas along the nearby Trent River, such as *Bouteloua curtipendula*, *Celtis tenuiflora*, *Gentiana alba*, *Solidago ptarmicoides*, and *Sporobolus heterolepis*. Many of the showy species occurring in prairie and savanna further to the west in Ontario such as *Euphorbia corollata*, *Liatris spicata*, *Viola pedata*, *V. pedatifida*, and *Solidago rigida* evidently never occurred on the Rice Lake Plains, whereas other species rare or absent in Ontario prairies to the west, such as *Castilleja coccinea*, *Liatris cylindracea*, *Lupinus perennis*, *Polygala polygama*, and *Prunus susquehannae* were present or even abundant. In addition, *Carex richardsonii*, *Panicum perlongum* and *P. praecocius* are frequent in remnants of the Rice Lake Plains, but apparently rare in the prairies of southwestern Ontario. Consequently, the Rice Lake Plains, and other sites in the central region of southern Ontario, represent a particular type of prairie and savanna. Without the reliable historical record this would have been less clear because only a small fraction of a percentage of the Rice Lake Plains vegetation is left, altogether an insufficient basis for any conclusions regarding composition. Additionally, the fact that most of the species present historically are currently found in one or more of several isolated relicts, suggests that these relicts are indeed representative of the Rice Lake Plains type of prairie and savanna, and thus appropriate for protection on that basis.

Maintenance of Prairie Vegetation

Traill (1836) writes: "these plains were formerly famous hunting-grounds of the Indians, who, to prevent the growth of timbers, burned them year after year ... Sufficient only was left to form coverts; for the deer resort hither in great herds for the sake of a peculiar tall sort of grass with which these plains abound, called deer-grass, on which they become exceedingly fat at certain seasons of the year." Traill identified "Deergrass" in 1885 (p. 102) as *Sorghum nutans* (now *Sorghastrum nutans*) and *Andropogon furcatus* (now *Andropogon gerardii*), and noted again that it was to increase the growth of these grasses that Indians set fire to the plains. The early surveyors, Hambly (1795a) and Roche (1847), also alluded to fires in the plains of Hamilton Township (see above). Curtis (1959) and Day (1953) provide ample evidence that Indians maintained open areas with fire and they cite references that suggest that it was done to

improve visibility for hunting and provide grass for elk and deer. Thus Traill's suggestion is strongly supported. Furthermore Traill (1885 p. 103) notes that the Indian name for Rice Lake, "Pemadashdakota" meant "The lake of the burning plains".

Of course, fire would not have been essential to maintain all of the prairie vegetation. Some remnants existing today on dry slopes have not been burned for many years. Traill (1885) noted that there had been no fires "within the memory of the oldest settler in the township of Hamilton", yet she reported extensive grassy areas. On the other hand, Roche (1847) reported that parts of the plains in Hamilton were "generally on fire during the summer months". The frequency of fires due to lightning may have been enough to maintain extensive and continuous prairie and savanna. However, there can be little doubt that a higher frequency of fire would have extended the prairie to its maximum area and maintained it in wetter sites than would have been possible with natural fires alone.

For fires set by Indians to have had a significant effect, there would need to be a long history of Indian occupation. Indian artifacts have been found throughout much of the Rice Lake Plains area (e.g., Martin et al. 1986). There is evidence that it was inhabitated by Indians "from very ancient times" (Kidd 1957) and up to 11 500 years ago (Martin *et al.* 1986). Frobisher (1785) found Mississaga villages along the Trent in 1785 and noted that they grew corn. Paudash (1904) noted that there were numerous Mohawk settlements on Rice Lake prior to the Mississaga occupation. The Hopewell culture occupied the area 2000 years ago (Kidd 1957) leaving the Serpent Mounds as a record of their occupation. The Hopewellians cultivated corn, beans, squash and tobacco. Approximately 3700 years ago the Late Archaic Indian culture occupied the McItnyre site on the north shore of Rice Lake (Johnston 1984). Clearly there is a long history of occupation and an unusually continuous record as well.

Rice Lake was part of a major Indian trade route linking Georgian Bay with Lake Ontario (Cristall et al. 1973; Frost 1973; Kidd 1957), via both the Trent River, possibly but not necessarily using the Percy Portage (Cristall et al. 1973), to the Bay of Quinte and the Ganaraska portage to the Indian trading village of Ganaraska, or at the time of settlement Smith's Creek (on the present site of Port Hope). Furthermore, the Rice Lake area was well suited to agriculture, an excellent hunting ground, and there were probably extensive beds of wild rice[3] in Rice Lake for a long period (McAndrews 1984), this being an important food item.

Northeastern prairies are strongly associated with Indian villages (e.g., Day 1953; Reznicek 1983). However, this could be coincidental to a degree since the soil conditions appropriate for Indian agriculture are also conducive to the maintenance of prairie vegetation, and the location of villages may have been influenced by accessibility of good prairie hunting grounds. Drought and natural fire could have maintained some northeastern prairie vegetation. However, there is every reason to believe that Indians maintained much more extensive prairie areas through clearing for agriculture, wood cutting and burning than would otherwise have existed in the Rice Lake area, and in other areas in the northeast such as western New York State (Day 1953).

Destruction of the Natural Vegetation

While it may be possible to determine the postglacial history of the Rice Lake Plains, no study of this aspect has yet been undertaken. It seems probable, however, that the plains existed for several thousand years, as recently demonstrated for Oak savanna near Brantford in southwestern Ontario (Szeicz and MacDonald 1991).

The settlement of the plains occurred a little later than in the surrounding wooded areas because the early settlers, with experience in the British Isles, thought that they could not grow crops in naturally open areas where there were no trees (Martin, McGillis and Milne 1986), contrary to the general contention of Wood (1961). The early settlers in the "Oak Openings" of western New York had a similar reaction (Day 1953). Traill noted that there were only five or six settlers on the Rice Lake Plains in 1832 and miles of unbroken land lay between them. She describes the plains as a "pathless wilderness" in 1837, that had been enclosed and cultivated by the time of her writing in 1885 (see page 49 under Lupine). The natural vegetation was probably destroyed mostly between 1875 and 1885, since in some of her unpublished manuscripts and notes Traill indicates that there were few settlements on parts of the plains, even in 1875. While some prairie plants have been found throughout the region, extensive prairie and savanna associations were thought to have been totally destroyed until 1989 when some impressive stands were discovered.

Considering what is known about the original extent of prairie and savanna in southern Ontario, and what is left, it appears to have been reduced to a much smaller fraction of its original extent than other high protection-priority communites such as

[3]Charles Fothergill (1817) reported 10 000 bushels of wild rice collected in Rice Lake each year.

wetlands and Carolinian woodlands. Remnants of the Rice Lake Plains, recently discovered by the authors, account for less than 1/1000th of a percentage of the original area. Not surprisingly, many of the plants and animals that occupy the prairie and savanna habitats are either extirpated in Ontario, or very close to it [e.g., the eastern Elk (*Cervus canadensis canadensis*), the Greater Prairie Chicken (*Tympanuchus cupido*), the Blue Racer snake (*Coluber constrictor foxii*), numerous insects including the Regal Fritillary butterfly (*Speyeria idalia*), the Karner Blue butterfly (*Lycaeides melissa samuelis*), the Frosted Elfin butterfly (*Incisalia irus*), etc., and a host of plants such as the white and blue Prairie Gentians (*Gentiana alba* and *G. puberulenta*)]. Although the situation with the protection of prairie and savanna is particularly distressing in Ontario, even to the Midwest where prairie and savanna were the dominant feature, the existing remnants require more characterization and research to enable appropriate protection. To adequately preserve biodiversity, it will be necessary to protect and manage as many of the small, scattered remnants of prairie and savanna as possible, and it will be desirable to practice restoration as well. Fortunately a substantial information base on management and restoration of prairie and savanna has been acquired over the past few decades (e.g., Mlot 1990).

Conclusions

The Rice Lake Plains, north of central Lake Ontario, was an extensive, continuous prairie and savanna extending over an area of at least 172 km^2 (66 square miles) and possibly as much as 250–300 km^2 (96–111 square miles). It was dominated by prairie grasses and included many other characteristic prairie and open ground species that are now rare or restricted in Ontario. The flora of the Rice Lake Plains differed from that of prairie and savanna further to the west in Ontario, and represents a particular kind of prairie and savanna that occurred in the central region of southern Ontario. Despite the fact that remnants account for less than 1/1000th of a percentage of the original plains area, they are representative based on the historical record. The Rice Lake Plains was a large patch of prairie and savanna within a much larger region, corresponding approximately to the eastern portion of the Oak Ridges moraine (*see* Chapman and Putnam 1984), that included many similar, but probably smaller, patches. This region north of Lake Ontario is the northeastern limit of extensive prairie and savanna vegetation (excluding certain rivershores, such as the middle Ottawa River, where there are very narrow bands of prairie grasses). Other extensive areas of prairie and savanna also existed in southern Ontario, and these community types were evidently a prominant feature of the southern Ontario landscape in presettlement times. The prairie and savanna vegetation of the Rice Lake Plains was probably maintained by a combination of edaphic factors, and both natural fires and fires caused by Indians.

Acknowledgments

Anton A. Reznicek of the University of Michigan, Steve Varga of the Ontario Ministry of Natural Resources, Central Region, Howard Savage of the Faunal Lab, Department of Anthropology, University of Toronto, J. Cayouette and W. J. Cody of the Biological Resources Division, Agriculture Canada, Marlin Bowles of the Morton Arboretum, Hazel Bird of Harwood, Norma Martin of Belleville (previously Gore's Landing) and D. F. Brunton of Ottawa, all provided useful comments and suggestions. J. Cayouette assisted extensively in the location of older literature. W. A. Waiser of the University of Saskatchewan checked his extensive files and his notes on archival material for the Northumberland list. M. Shchepanek of the Canadian Museum of Nature (Ottawa) kindly searched the botany library. Adele Crowder of Queens University kindly searched the Queens library and archives.

Literature Cited

Adams, J. 1928. A bibliography of Canadian plant geography to the end of the year 1920. Transactions of the Royal Canadian Institute 16: 293–355.

Alison, R. M. 1976. The history of the Wild Turkey in Ontario. Canadian Field-Naturalist 90: 481–485.

Bakowsky, W. D. 1988. The phytosociology of midwestern savanna in the Carolinian region of southern Ontario. M.Sc. thesis, University of Toronto. 121 pages + 4 appendices.

Birdsall, R. 1824. Resurvey and correction of the eastern side line of township of Cramahe. Field Notebook 141. Department of Surveys Book of Field Notes 8: 347–356.

Birdsall, R. 1826. Alnwick Township. Field Notebook 37. Department of Surveys Book of Field Notes 18: 165–181.

Boivin, B. 1980. Survey of Canadian herbaria. Provancheria 10. 187 pages.

Bray, J. R. 1955. The savanna vegetation of Wisconsin and an application of the concepts, order and complexity to the field of ecology. Ph.D. thesis, University of Wisconsin. 174 pages.

Bray, J. R. 1960. The composition of savanna vegetation in Wisconsin. Ecology 41: 671–681.

Catling, P. M., and **S. M. McKay.** 1974. An interesting association of plants along a railway track at West Hill, Ontario. Ontario Field Biologist 28: 1–27.

Catling, P. M., and **R. Hélie.** 1990. Representivity workshop. Pages 91–98 *in* Canadian Council on Ecological Areas Annual Meeting, Ottawa, 1990. *Edited by* J. R. Reid. Canadian Council on Ecological Areas, Occasional Paper No. 10.

Chapman, L. J., and **D. F. Putnam.** 1984. The physiography of Southern Ontario. Third edition. Ontario Geological Survey, Special Volume 2. 270 pages.

Cristall, F., G. Holyer, B. Hood, R. Hood, and **B. Lind-Peterson.** 1973. The Percy Portage. Trent University Press. 179 pages.

Curtis, J. T. 1959. The vegetation of Wisconsin. University of Wisconsin Press. Madison. 657 pages.

Day, G. M. 1953. The Indian as an ecological factor in the northeastern forest. Ecology 34: 329–346.

Dore, W. G. 1966. Grasses from Stony Lake gathered and mounted by Catharine Parr Traill — aged 92 years. Ontario Naturalist 4(2): 17–21.

Drummond, A. T. 1867. The distribution of plants in Canada. Canadian Naturalist, 2nd series, 3: 161–177.

Faber-Langendoen, D. 1984. The ecology of tallgrass prairie in southern Ontario. M.Sc. thesis, University of Toronto. 205 pages.

Faber-Langendoen, D., and **P. F. Maycock.** 1987. Composition and soil environment analysis of prairies on Walpole Island, southwestern Ontario. Canadian Journal of Botany 65: 2410–2419.

Fothergill, C. 1817. A few notes made on a journey from Montreal through the province of Upper Canada in February, 1817. [Diary in Rare Books Library, University of Toronto].

Frobisher, B. 1785. Letter dated 2 May 1875. Public Archives of Canada, C. O. 42, volume 47, and pages 132–136 *in* The valley of the Trent. *Edited by* E. C. Guillet (1957). Champlain Society and University of Toronto. 474 pages.

Frost, L. M. 1973. Forgotten pathways of the Trent. Burns & MacEachern, Don Mills, Ontario. 111 + 1 pages.

Greeley, A. 1796a. Minutes of township of Percy. Field Notebook 286. Department of Surveys Book of Field Notes 2: 19–28.

Greeley, A. 1796b. Minutes for the townships of Haldimand and Cramahe. Field Notebook 346. Department of Surveys Book of Field Notes 2: 95–114.

Hambly, W. 1795a. Field notes for the township of Hamilton. Department of Surveys Book of Field Notes 2: 35–41.

Hambly, W. 1795b. Notes on S line of township N of Cramahe (Percy). Department of Surveys Book of Field Notes 2: 42–47.

Hoffman, D. W., and **C. J. Acton.** 1974. The soils of Northumberland County. Ontario Soil Survey Report No. 42. Agriculture Canada Research Branch. 117 pages + map.

Holmgren, P. K., W. Keuken, and **E. K. Schofield.** 1981. Part 1. The herbaria of the world. 7th edition. 452 pages. *In* Index Herbariorum. *Edited by* F. A. Stafleau. Bohn, Scheltema and Holkema, Utrecht.

Johnston, R. B., *Editor.* 1984. The McIntyre site: archaeology, subsistence and environment. National Museum of Man, Archaeological Survey of Canada, paper no. 126. 189 pages.

Kent, D. H., and **D. E. Allen.** 1984. British and Irish herbaria, an index to the location of herbaria of British and Irish vascular plants. Botanical Society of the British Isles, London.

Kidd, K. E. 1957. Discovery of the Trent valley, and its native inhabitants. Pages 3–6 *in* The valley of the Trent. *Edited by* E. C. Guillet. Champlain Society, Toronto. 474 pages.

Langendoen, D., and **P. F. Maycock.** 1983. Preliminary observation on the distribution and ecology of tallgrass prairie in southern Ontario. Pages 92 – 97 *in* Proceedings of the 8th North American Prairie Conference. *Edited by* R. Brewer. Western Michigan University, Kalamazoo, Michigan. 175 pages.

[Lawson, G.] 1863. Botanical Society of Canada. Canadian Naturalist and Geologist 8: 76–80.

Lawson, G. 1884. Revision of the Canadian Ranunculaceae. Transactions of the Royal Society Canada. II, section IV: 15–90.

Lumsden, H. G. 1966. The prairie chicken in southwestern Ontario. Canadian Field-Naturalist 80: 33–45.

Macoun, J. 1867. Letter to A. T. Drummond. Drummond Papers. Queens University Archives [xerox in Biological Resources Division Botany Library, Agriculture Canada].

Macoun, J. 1876. The rare plants of the province of Ontario. Transactions of the Botanical Society (Edinburgh) 12: 300–334.

Macoun, J. 1883. Catalogue of Canadian plants. part I – Polypetalae. Dawson Brothers, Montreal. 194 pages.

Macoun, J. 1884. Catalogue of Canadian plants. part II - Gamopetalae. Dawson Brothers, Montreal. Pages 194–394.

Macoun, J. 1886a. Catalogue of Canadian plants. part III - Apetalae. Dawson Brothers, Montreal. Pages 396–476.

Macoun, J. 1886b. Catalogue of Canadian plants. Additions to parts I - II. Dawson Brothers, Montreal. Pages 477–623.

Macoun, J. 1888. Catalogue of Canadian plants. part IV - Endogens. Dawson Brothers, Montreal. Pages 1–248.

Macoun, J. 1890a. Catalogue of Canadian plants. part V - Acrogens. Dawson Brothers, Montreal. Pages 249–294.

Macoun, J. 1890b. Catalogue of Canadian plants. Additions and corrections to parts I-IV. Dawson Brothers, Montreal. Pages 295–428.

Macoun, J. 1922. Autobiography of John Macoun, M. A., Canadian explorer and naturalist. Ottawa Field-Naturalists' Club. 303 pages.

Macoun, J., and **J. Gibson.** 1876. Synopsis of the flora of the valley of the St. Lawrence and Great Lakes. Canadian Journal (July): 1–16.

Macoun, J., and **J. Gibson.** 1877. Synopsis of the flora of the valley of the St. Lawrence and Great Lakes. Canadian Journal (April & July): 1–20.

Martin, N., D. S. McGillis, and **C. Milne.** 1986. Gore's Landing and the Rice Lake Plains. Heritage Gore's Landing, Ontario. 294 pages.

McAndrews, J. H. 1984. Late quaternary vegetation history of Rice Lake, Ontario, and the McIntyre archaeological site. Pages 161–189 *in* The McIntyre site: archaeology, subsistence and environment. *Edited by* R. B. Johnston. National Museum of Man, Archaeological Survey of Canada, paper no. 126. 189 pages.

Mlot, C. 1990. Restoring the prairie. Bioscience 40: 804–809.

Morris, A. Y. 1966. Gentle Pioneers. Hodder & Stoughton, Toronto. 253 pp.

Needler, G. H. 1946. The Otonabee trio of woman naturalists: Mrs. Stewart — Mrs. Traill — Mrs. Moodie. Canadian Field-Naturalist 60: 97–101.

Nuzzo, V. A. 1986. Extent and status of midwest oak savanna: presettlement and 1985. Natural Areas Journal 6: 6–36.

Packard, S. 1991. Rediscovering the tallgrass savanna of Illinois. Pages 55–66 *in* Proceedings of the Oak Woods Management Workshop. *Edited by* G. W. Burger, J. E. Ebinger and G. S. Wilhelm. Eastern Illinois University. 106 pages.

Paudash, R. 1904. The coming of the Mississagas. Ontario History Society Papers And Records. Pages 9–13 *in* The valley of the Trent. *Edited by* E. C. Guillet. Toronto. 474 pages.

Pratt, P. 1979. A preliminary life science inventory of the Ojibway Prairie complex and surrounding area. Corporation of the city of Windsor Parks and Recreation Department and the Ontario Ministry of Natural Resources. 163 pages.

Reznicek, A. A. 1980. John Goldie's 1819 collecting site near Lake Simcoe, Ontario. Canadian Field-Naturalist 94: 439–442.

Reznicek, A. A. 1983. Association of relict prairie flora with Indian trails in central Ontario. Pages 33–39 *in* Proceedings of the 8th North American Prairie Conference. *Edited by* R. Brewer. Western Michigan University, Kalamazoo, Michigan. 175 pages.

Reznicek, A. A., and **P. F. Maycock.** 1983. Composition of an isolated prairie in central Ontario. Canadian Journal of Botany 61: 3107–3116.

Roche, J. K. 1845. Survey of the front of the 7th, 8th, 9th and 10th concessions of Hope Township. Department of Surveys, Field Notebook 1310. 56 pages.

Roche, J. K. 1847. Hamilton Township. Department of Surveys, Field Notebook 821. 90 pages.

Rogers, C. M. 1966. A wet prairie community at Windsor, Ontario. Canadian Field-Naturalist 80: 195–199.

Root, I. [no date]. A survey of the township of Hamilton. Transcribed to the Department of Surveys, Book of Field Notes 2: 48–59.

Rubidge, F. P. 1835. Alnwick Township. Field notebook 322. 6 pages. Department of Surveys, Book of Field Notes 18: 182–188.

Schmidt, K. P. 1938. Herpetological evidence for post glacial eastward extension of the steppe in North America. Ecology 19: 396–407.

Smith, J. 1827. General account of the Newcastle District, 1827. Page 31 *in* The valley of the Trent. *Edited by* E. C. Guillet. Champlain Society, Toronto. 474 pages.

Strickland, S. 1853. [reprinted 1954]. Twenty-seven years in Canada West, or the experience of an early settler. M. G. Hurtig Ltd., Edmonton. [2 volumes in one, not numbered.]

Sziecz, J. M., and **G. M. MacDonald.** 1991. Postglacial vegetation history of Oak savanna in southern Ontario. Canadian Journal of Botony 69: 1507–1519.

Traill, C. P. 1836. The backwoods of Canada. Charles Knight, London. [Reprinted 1989 by MacClelland and Stewart Inc., Toronto. 301 pages.]

Traill, C. P. 1868. Canadian Wildflowers. John Lovell, Montreal. 86 pages + 10 plates.

Traill, C. P. 1885. Studies of plant life in Canada or gleanings from forest, lake and plain. A. S. Woodburn, Ottawa. 288 pages.

Transeau, E. N. 1935. The prairie peninsula. Ecology 16: 423–437.

Varga, S. 1989. A botanical inventory and evaluation of the High Park Oak Woodlands Area of Natural and Scientific Interest. Ontario Ministry of Natural Resources. 48 pages + 2 maps.

Waiser, W. A. 1989. The field-naturalist John Macoun, the geological survey, and natural science. University of Toronto Press. 253 pages.

Watkins, S. 1795a. Field notes of the township of Haldimand. Field Notebook 437. Transcribed to the Department of Surveys Book of Field Notes 2: 32–34.

Watkins, S. 1795b. Report of a survey made at Cramahe, Haldimand and the township in the rear of Haldimand (Alnwick). Transcribed to Department of Surveys Book of Field Notes 2: 8–12.

Weatherby, C. A. 1941. Lawson's type specimens. American Fern Journal 31(2): 59–62.

Wood, J. D. 1961. The woodland-oak plains transition zone in the settlement of western Upper Canada. Canadian Geographer 5: 43–47.

Received 12 December 1991
Accepted 23 February 1992

Vascular Plant Flora of the Melville Hills Region, Northwest Territories

WILLIAM J. CODY[1], GEORGE W. SCOTTER[2,4], AND STEVE C. ZOLTAI[3]

[1]Centre for Land and Biological Resources Research, Agriculture Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6
[2]Canadian Wildlife Service, Rm. 210, 4999 – 98 Avenue, Edmonton, Alberta T6B 2X3
[3]Northern Forestry Centre, 5320 – 122 Street, Edmonton, Alberta T6H 3S5
[4]Present Address: R.R.4, S9–C15, 399 Oakview Road, Kelowna, British Columbia VIY 7R3

Cody, William J., George W. Scotter, and Steve C. Zoltai. 1992. Vascular plant flora of the Melville Hills Region, Northwest Territories. Canadian Field-Naturalist. 106(2): 87–99.

Two hundred and thirty-seven species of vascular plant taxa are reported from the Melville Hills region as a result of 10 days of field surveys of 39 localities in 1990. The Melville Hills region lies entirely beyond the treeline. A portion of the region was not glaciated during the latest Wisconsin glaciation. Phytogeographic affinities of the known flora of 237 taxa are 53.8% circumpolar, 11% amphi-Beringian, 3.8% amphi-Atlantic, and 31.4% North American.

Key Words: Vascular plants, Melville Hills, Northwest Territories, phytogeographic affinities.

The Melville Hills are located in the northeastern section of the District of Mackenzie, between longitudes 119°W and 123°W, south of Amundsen Gulf of the Arctic Ocean. A natural resource survey of this region was undertaken by the Canadian Wildlife Service and Forestry Canada during 1990, because of the potential of this area as a national park or national wildlife area. The flora of this area is virtually unknown, as previous records were mainly from coastal areas between Coppermine on the east and Paulatuk to the west (Porsild and Cody 1980). The purpose of this paper is to report the vascular plants collected during the 1990 survey. A few plants were collected at Paulatuk which is west of the study area.

Study Area

The study area is centered on the Melville Hills, occupying an area of approximately 33 000 km^2 (Figure 1). The Melville Hills rise gradually to a maximum height of 876 m ASL (Above Sea Level). The hills are drained by the Hornaday River and Brock River towards the west, eroding deep canyons near the coast. Bluenose Lake, a large (400 km^2) lake on the eastern flank of Melville Hills, is drained northward by the Croker River. The hills are largely composed of nearly horizontally bedded Precambrian sandstone, with local basaltic intrusive rocks. Poorly consolidated sedimentary rocks of Cretaceous age occur on the lowlands west of Melville Hills.

The Melville Hills were not glaciated during the latest Wisconsinan glaciation (Dyke and Prest 1987). Ice flow pattern suggests that the late-Wisconsin glacier ice, advancing from the southeast, was deflected around Melville Hills (Craig 1960). Wood, identified as *Pinus strobus* type (R. Mott, personal communication), was found on the shores of a large lake at the headwaters of the largest tributary of Hornaday River. This wood was dated as > 41 000 BP (Before Present) by the Geological Survey of Canada (GSC-5115). The central portion of Melville Hills has no glacial erratics, suggesting that perhaps a small portion of the uplands may have totally escaped glaciation. Although the understanding of glacial time sequence of this area requires more studies, it seems that the Melville Hills were free of ice for a much longer period of time than the rest of the neighbouring Arctic mainland.

The climate is characterized by long, cold winters and low amounts of precipitation. At Clinton Point on the Amundsen Gulf coast the mean annual temperature is –11.2°C, and the mean July temperature is 7.4° (Environment Canada 1982), but frost can occur even during the summer months. The mean cumulative annual degree days above 5° is 203°. The mean annual precipitation is 181.5 mm, about half of which occurs as snow.

Permafrost occurs under all land surfaces. The seasonally thawed layer is generally the thinnest (25 cm) in the poorly–drained peaty soils, becoming thicker (60 cm) in the well–drained loamy soils common in the area. In the dry sandy or gravelly soils the active layer may be up to 1 m thick. The surface is commonly frost heaved into sorted or non-sorted patterns, indicating extreme instability in the rooting zone of plants. Ground ice segregation occurs frequently in ice wedges, or rarely, in pingos. The vegetation is influenced by regional differences in elevation, soil materials and climate. Local site conditions such as drainage, exposure, and physiography further affect the vegetation distribution. In the well protected valleys of the lower Hornaday and Brock rivers, tall willow shrubs and continuous tundra vegetation grows. At higher elevations the vege-

tation cover is discontinuous, with low, ground-hugging shrubs, forbs, and sedges. The wet sites are dominated by sedges and cottongrass, as well as mosses. In the exposed bedrock and rock rubble areas crustose and umbilicate lichens dominate, with only scattered dwarf shrubs and mosses.

Methods

The survey was carried out during ten days (24 July to 2 August 1990) with helicopter support. This allowed GWS and SCZ to examine a range of habitats including situations that had been covered by late snow patches. At each site transects were run in random directions to intersect a variety of habitats and vegetation types. Plants were collected along the transects for later identification and preservation. In all, representatives of a total of 237 taxa of vascular plants were collected from the area and this is considered to be a reasonably complete list.

Because most of these represented new localities for the species as shown in the maps presented in Porsild and Cody (1980), comments are presented in the following list by reference to those maps. In addition to the vascular plants, collections of mosses and lichens were also made and are reported separately (Scotter and Vitt 1992; Thomson and Scotter 1992).

Study Sites

In the course of the survey, 39 sites with vascular plants were studied. The locations of these sites are indicated on Figure 1. Latitudes, longitudes and elevations in meters above sea level of the collection sites from which specimens are cited in this paper (given in parentheses after voucher number) are listed below. The broad landform of the sites are also noted. "Old till" refers to other than late-Wisconsinan deposits, and "residual" surfaces were apparently unaffected by glaciation. All other landforms are of late-Wisconsinan or Holocene age.

1. Paulatuk, 69°21'N, 124°05'W, 1 m, 24 July 1990.
   Eroding sandy seashore.
2. "Hornaday Lake", 68°42'N, 120°48'W, 513 m, 24 July 1990.
   Old till plain, with modern lakeshore.
3. 68°49'N, 120°45'W, 540 m, 25 July 1990.
   Old till plain.
4. 68°36'N, 120°24'W, 580 m, 25 July 1990.
   Old till plain, with wet meadow.
5. 68°26'N, 119°50'W, 560 m, 25 July 1990.
   Till plain, with kame.
6. 68°33'N, 120°38'W, 710 m, 25 July 1990.
   Old till plain, with kame.
7. Hornaday River, 68°33'N, 120°46'W, 490 m, 25 July 1990.
   Old till plain, with modern riverbank.
8. 68°44'N, 121°03'W, 660 m, 26 July 1990.
   Old till plain upland, with kame.
9. 68°39'N, 121°15'W, 730 m, 26 July 1990.
   Peat polygons on old till plain.
10. Hornaday River, 68°36'N, 120°41'W, 510 m, 26 July 1990.
    Sandstone bedrock cliff, with modern riverbank.
11. 68°09'N, 120°32'W, 570 m, 26 July 1990.
    Limestone rubble on old till plain, with meadow below perennial snowbank.
12. 68°17'N, 121°14'W, 510 m, 26 July 1990.
    Peat polygons on old till plain.
13. Croker River Canyon, 69°06'N, 119°30'W, 340 m, 27 July 1990.
    Dolomitic sandstone bedrock plain.
14. Croker River Delta, 69°17'N, 119°07'W, 2 m, 27 July 1990.
    Modern seashore and marine plain.
15. "Conglomerate Hill", 69°21'N, 119°57'W, 30 m, 27 July 1990.
    Till over conglomerate bedrock.
16. "Diabase Canyon", 69°17'N, 120°21'W, 275 m, 27 July 1990.
    Deep canyon in diabase bedrock.
17. 69°18'N, 119°56'W, 180 m, 27 July 1990.
    Small canyon in dolomitic sandstone.
18. 68°34'N, 121°05'W, 550 m, 28 July 1990.
    Meadow below perennial snowbank on a till plain.
19. 68°27'N, 121°10'W, 550 m, 28 July 1990.
    Valley among diabase cliffs.
20. 69°43'N, 121°17'W, 5 m, 29 July 1990.
    Till plain with dolomitic sandstone rubble.
21. 69°47'N, 121°52'W, 55 m, 2 July 1990.
    Till plain with perennial snowbank.
22. 69°48'N, 121°53'W, 2 m, 29 July 1990.
    Modern marine beach.
23. Lower Brock Lagoon, 69°31'N, 123°13'W, 2 m, 29 July 1990.
    Modern marine delta.
24. 69°08'N, 121°50'W, 700 m, 29 July 1990.
    Meadow on residual upland surface.
25. 68°32'N, 121°31'W, 750 m, 30 July 1990.
    Upland on residual surface.
26. 68°23'N, 122°06'W, 480 m, 30 July 1990.
    Narrow valley in dolomitic sandstone.
27. 68°14'N, 122°38'W, 510 m, 30 July 1990.
    Pingo on exposed modern lakebed.
28. Hornaday River, 67°59'N, 121°32'W, 440 m, 30 July 1990.
    Glaciofluvial sand and gravel ridge.
29. Confluence of Hornaday River and a river from an unnamed lake, 68°20'N, 121°57'W, 380 m, 30 July 1990.
    Modern fluvial floodplain.
30. La Ronciere Falls, 69°08'N, 122°52'W, 215 - 275 m, 31 July 1990.
    Deep canyon in dolomitic sandstone.
31. Pearce Point, 69°49'N, 122°38'W, 2 m, 31 July 1990.
    Slopes of marine clay.

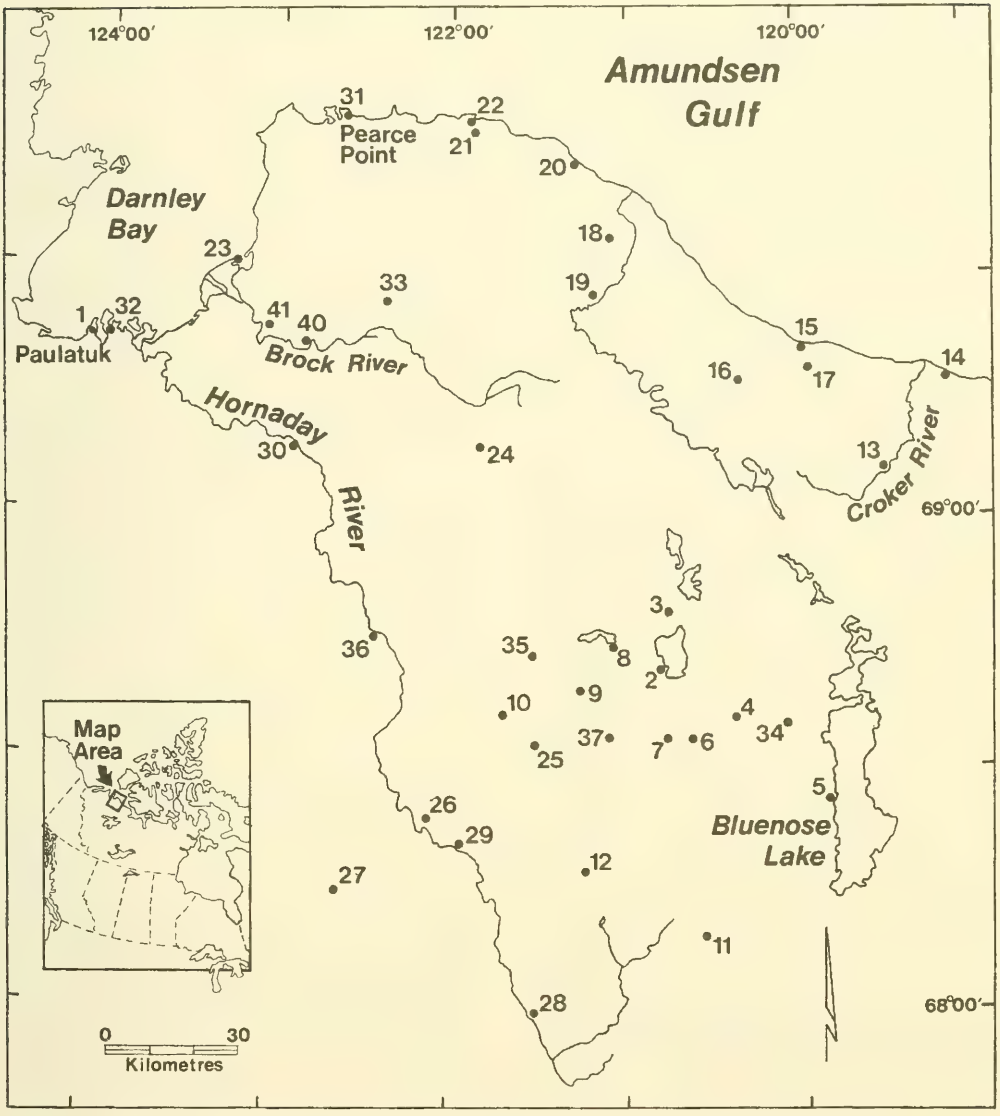


FIGURE 1. Locations of survey sites in the Melville Hills region, Northwest Territories.

32. Hornaday Delta, 69°22'N, 123°56'W, 5 m, 31 July 1990.
Modern marine delta.

33. 69°26'N, 122°23'W, 430 m, 31 July 1990.
Old till plain.

34. 68°35'N, 120°05'W, 620 m, 1 August 1990.
Old till plain with limestone cliff.

35. 68°42'N, 121°31'W, 710 m, 1 August 1990.
Upland on residual surface.

36. 68°46'N, 122°25'W, 420 m, 1 August 1990.
Modern river bank and till.

37. 68°33'N, 121°05'W, 520 m, 1 August 1990.
Till plain.

38. 69°05'N, 121°37'W, 700 m, 2 August 1990.
Upland on residual surface.

39. 69°11'N, 121°49'W, 795 m, 2 August 1990.
Rock rubble on residual surface.

40. Brock Canyon, 69°21'N, 122°48'W, 300 m, 2 August 1990.
Deep canyon in dolomitic sandstone.

41. Lower Brock River, 69°23'N, 123°04'W, 60 m, 2 August 1990.
Modern river banks and steep till slope.

Annotated Species List

Because of the historical difficulty of access to the Melville Hills Region, very few plant collections have been made previously. In 1963, J. A. Parmalee, Mycologist, Biosystematics Research Centre (in part a predecessor of the Centre for Land and Biological Resources Research), Agriculture Canada, made a collection of vascular plants while studying fungi in the vicinity of the former DEW Line site at Pin 1, Clinton Point, and in 1969, Guy Shewell, Entomologist, Biosystematics Research Centre, gathered a few specimens during a brief stop at "Fraser Lake" within the study area. These specimens have been available for study in the Agriculture Canada herbarium and the sites are mentioned in the text below.

In the list of vascular plants which follows, the collection numbers are those of GWS. The locality number is given in parentheses following the collection number. The voucher collections have been deposited in the herbarium of the Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa (DAO) and duplicate specimens, when available, have been deposited in the herbarium of the Northern Forest Research Centre, Forestry Canada, Edmonton (CAFB). The taxonomy follows Porsild and Cody (1980), or if otherwise, synonymy is given. Common names for the most part follow those in Porsild and Cody (1980) or Welsh (1974), however, it should be noted that many northern plants do not have common names or may only be called the common name given to the genus. In addition to the distribution maps published in Porsild and Cody (1980), which depict the known ranges to that time in the continental Northwest Territories, the authors consulted the more detailed, larger scale manuscript maps of A. E. Porsild on which the published ones were based. Phytogeographic affinities of the known flora of 237 taxa are 53.8% circumpolar, 11% amphi-Beringian, 3.8% amphi-Atlantic, and 31.4% North American.

The following species are of particular interest: *Phlox richardsonii* and *Mertensia drummondii* are endemic to the northwestern part of the Northwest Territories and Northern Alaska. Their presence here may help support the hypothesis of unglaciation. *Salix hastata, S. phlebophylla, Papaver macounii, Draba incerta, Potentilla biflora* and *Gentiana prostrata* represent considerable extensions of their previously known range eastwards to the survey area. *Puccinellia angustata*, and *Papaver cornwallisensis* are new to the District of Mackenzie and *Cerastium regelii* is the second report for that territory. *Draba subcapitata* is here reported for the first time from the Continental Northwest Territories. *Castilleja hyperborea* is at its known easternmost limit of distribution. *Pedicularis flammea* is an Amphi-Atlantic species apparently at its northwestern limit of distribution.

ASPIDIACEAE

Cystopteris fragilis (L.) Bernh., Fragile Fern, *90–444*(15); *90–468*(17); *90–676*, *90–677*, *90–685*(30); *90–723*(34); *90–747*(40). Circumpolar, from high arctic to temperate regions.

Woodsia glabella R.Br., Smooth Woodsia, *90–486*(19); *90–678*, *90–679*, *90–680*(30); *90–748*(40). Circumpolar, arctic-alpine.

EQUISETACEAE

Equisetum arvense L., Common Horsetail, *90–146*(20); *90–190*(3); *90–210*(4); *90–399*(14); *90–510*(21); *90–636*(20); *90–749*(40). Circumpolar, high arctic to temperate regions.

Equisetum palustre L., Marsh Horsetail, *90–352*(11); *90–477*(19); *90–538*(23). Circumpolar-boreal; a range extension of the known distribution northward of some 100 km from the north shore of Great Bear Lake and some 550 km eastward from the Mackenzie River Delta.

Equisetum scirpoides Michx., Dwarf Scouring-Rush, *90–470*(18); *90–476*(19). Circumpolar, low arctic to temperate.

Equisetum variegatum Schleich., Variegated Horsetail, *90–145*(2); *90–191*(3); *90–398*(14); *90–736b*(36). Circumpolar, arctic-alpine to temperate.

LYCOPODIACEAE

Lycopodium selago L., Mountain Club-Moss, *90–369*(12); *90–610*(26). Circumpolar, high arctic-alpine.

PINACEAE

Juniperus communis L., Ground Juniper, *90–686*(30). Circumpolar, temperate; an extension of the known range eastward along the Arctic Coast of some 250 km from Liverpool Bay and northward of some 250 km from the east end of Great Bear Lake.

SPARGANIACEAE

Sparganium hyperboreum Laest., Bur-Reed, *90–542*(23); *90–717*(32). Circumpolar, sub-arctic; an extension of the known range eastward of some 250 km from Liverpool Bay and north of some 300 km from the north shore of Great Bear Lake.

POTAMOGETONACEAE

Potamogeton filiformis Pers., Pondweed, *90–541*(23). Circumpolar, low-arctic-temperate; an extension of the known range of some 325 km eastwards from the Tuktoyaktuk Peninsula, of some 360 km, northwards from the north shore of Great Bear Lake and some 650 km north-westwards from the south end of Bathurst Inlet.

Potamogeton vaginatus Turcz., Pondweed, *90–494*(20). Circumpolar, low-arctic-temperate; an extension of the known range of some 280 km east-

wards along the Arctic Coast from Liverpool Bay and 320 km northwards from the east end of Great Bear Lake.

SCHEUCHZERIACEAE

Triglochin maritimum L., Arrow-grass, *90–543*(23); *90–665*(29). Circumpolar, temperate; an extension of the known range eastwards along the Arctic Coast of some 160 km from southeast of Cape Bathurst, 100 km northwards from Great Bear Lake and 550 km northwestwards from the south end of Bathurst Inlet.

Triglochin palustre L., Arrow-grass, *90–544*(23). Circumpolar, temperate; an extension of the known range eastwards along the Arctic Coast from Liverpool Bay of some 200 km, northwards some 300 km from Great Bear Lake and 550 km northwestwards from Bathurst Inlet.

GRAMINEAE

Arctagrostis latifolia (R.Br.) Griseb. ssp. *latifolia, 90–068*(2); *90–286*(8); *90–298*(9); *90–507*(21). Circumpolar, arctic-alpine.

Arctagrostis latifolia (R.Br.) Griseb. ssp. *arundinacea* (Trin.) Tzvelev (*A. arundinacea* (Trin.) Beal), *90–526*(23). Amphi-Beringian. An up-to-date map of the known distribution is presented in Aiken and Lefkovitch (1990).

Arctophila fulva (Trin.) Anders., *90–297, 90–299*(9); *90–627*(27); *90–650*(28). Circumpolar, low-arctic.

Bromus pumpellianus Scribn. var. *pumpellianus*, Brome-grass, *90–521*(23). Western North America north to the arctic slope; a range extension eastwards of some 200 km from about 130°W longitude and some 300 km northwards from Great Bear Lake.

Bromus pumpellianus Scribn. var. *arcticus* (Shear) Porsild, *90–000*(1). Amphi-Beringian.

Calamagrostis canadensis (Michx.) Beauv. ssp. *langsdorfii* (Link) Hultén, Bluejoint, *90–621*(27). *C. canadensis* ssp. *canadensis*, Circumpolar, low-arctic-boreal.

Calamagrostis purpurascens R.Br., Purple Reedgrass, *90–010*(1); *90–071*(2); *90–326*(10); *90–506*(21); *90–592*(26); *90–625*, *90–629*(27). East Greenland to East Asia.

Calamagrostis stricta (Timm) Koeler (*C. neglecta* (Ehrh.) Gaertn., Mey. & Scherb.), *90–070*(2). Circumpolar-boreal.

Colpodium vahlianum (Liebm.) Nevski, *90–285*(8); *90–388*(14). Amphi-Atlantic, high-arctic.

Deschampsia brevifolia R.Br., Hair-Grass, *90–060, 90–062, 90–065*(2); *90–284*(8); *90–393*(14); *90–704*(31). Circumpolar, arctic-alpine.

Dupontia fisheri R.Br., *90–390*(14); *90–489, 90–490*(20); *90–527*(23). Circumpolar, high-arctic.

Elymus alaskanus (Scribn. & Merr.) A. Löve ssp. *hyperarcticus* (Polunin) A. & D. Löve (*Agropyron violaceum* (Hornem.) Lange var. *hyperarcticum* Polunin), Lyme-Grass, *90–001, 90–009*(1); *90–064*(2). North American arctic and high-arctic.

Festuca altaica Trin., Fescue, *90–662*(29); *90–759*(41). Amphi-Beringian; an extension of the known range eastwards of some 125 km from near the Anderson River and northwards of some 140 km from Great Bear Lake, based on the map published recently by Aiken and Darbyshire (1990).

Festuca baffinensis Polunin, *90–222*(5). North American, high-arctic-alpine south in Rocky Mts. to Wyoming and Colorado; previously known in the area from Clinton Point.

Festuca brachyphylla Schultes & Schultes f., *90–223*(5); *90–385*(14). Circumpolar, high-arctic-alpine; previously recorded in the area from approximately 120°W longitude.

Festuca richardsonii Hook. (*F. rubra* L. ssp. *richardsonii* (Hook.) Hultén), *90–384*(14); *90–428*(15); *90–710, 90–716*(32). North American, arctic-subarctic.

Festuca vivipara (L.) Smith ssp. *glabra* Frederiksen, *90–063*(2); *90–628*(27). Circumpolar with gaps, high arctic-alpine; an extension of the known range in northwestern North America of some 450 km eastwards and northeastwards from sites in the Mackenzie Mountains, and Northern Yukon National Park; to the east, the nearest known sites are northernmost Ellesmere Island and western Greenland.

Hierochloe alpina (Sev.) R. & S., Holy Grass, 90–593(26). Circumpolar, arctic-alpine.

Hierochloe pauciflora R.Br., *90–327*(10). Nearly circumpolar-arctic.

Leymus mollis (Trin.) Pilger ssp. *villosissimus* (Scribn.) A. Löve (*Elymus arenarius* L. ssp. *mollis* (Trin.) Hultén), *90–389*(14). Circumpolar, low-arctic, littoral.

Poa alpigena (Fries) Lindm., Blue Grass, *90–006, 90–008*(1). Circumpolar, arctic-alpine-boreal.

Poa arctica R.Br., Arctic Bluegrass, *90–386, 90–392*(14); *90–427*(15). Circumpolar, arctic-alpine; previously known from the Arctic Coast at about 120°W longitude.

Poa glauca M. Vahl, Glaucous Bluegrass, *90–003*(1); *90–066, 90–067, 90–069*(2); *90–178*(3); *90–221*(5). Circumpolar, arctic-alpine-boreal.

Puccinellia andersonii Swallen, Goose Grass, *90–520*(23). North American high-arctic; previously known on the Arctic Coast of District of Mackenzie only on Richards Island in the Mackenzie River Delta.

Puccinellia angustata (R.Br.) Rand & Redf., *90–391*(14); *90–703*(31). Circumpolar, high-arctic; not previously recorded from the Arctic Coast of the District of Mackenzie.

Puccinellia borealis Swallen, *90–072*(2); *90–622, 90–623, 90–626*(27). Amphi-Beringian.

Puccinellia deschampsioides Th. Sor., *90–624*(27). North American, arctic; rare, but previously known on the coast from just west of longitude 120°W.

Puccinellia langeana (Berl.) Th. Sor., *90–387*(14). North American, low-arctic; not previously recorded from the Arctic Coast of the District of Mackenzie but known from the southern shores of Victoria and Banks islands.

Puccinellia phryganodes (Trin.) Scribn. & Merr., *90–522, 90–523, 90–525, 90–528*(23). Circumpolar, arctic, littoral.

Puccinellia vaginata (Lange) Fern. & Weath., *90–524*(23). North American, arctic.

Trisetum spicatum (L.) Richt., Downy Oatgrass, *90–002, 90–004*(1); *90–061*(2). Circumpolar, arctic-alpine-boreal; previously known from a site near Clinton Point.

CYPERACEAE

Carex aquatilis Wahlenb., Sedge, *90–082, 90–085*(2); *90–179*(3); *90–307*(9); *90–631*(27). Circumpolar, non-arctic; an extension of the known range eastwards along the Arctic Coast of some 200 km from Liverpool Bay and north from the eastern end of Great Bear Lake of some 100 km.

Carex atrofusca Schk., *90–075, 90–080*(2). Circumpolar, high-arctic.

Carex bicolor All., *90–083*(2); *90–531*(23). Circumpolar, low-arctic.

Carex capillaris L. s.lat., *90–079*(2); *90–184*(3); *90–329*(10); *90–533, 90–536*(23); *90–632*(27); *90–651*(28). Circumpolar?, arctic-alpine.

Carex chordorrhiza Ehrh., *90–084*(2). Circumpolar, low-arctic.

Carex glacialis Mack., *90–287*(8). Circumpolar, arctic-alpine.

Carex lugens Holm, *90–012*(1). Amphi-Beringian, subarctic-alpine.

Carex maritima Gunn, *90–073, 90–074a*(2); *90–394*(14); *90–514*(22). Circumpolar, arctic.

Carex membranacea Hook., *90–013*(1); *90–081*(2); *90–181, 90–185*(3); *90–308*(9); *90–364*(12). Arctic North America to east Asia; previously known in the area from near Clinton Point.

Carex microglochin Wahlenb., *90–475*(19); *90–535*(23). Circumpolar with large gaps, low-arctic; a northward extension of the known range of some 300 km from the east end of Great Bear Lake northwest from the south end of Bathurst Inlet of some 650 km.

Carex misandra R.Br., *90–076, 90–087, 90–091*(2); *90–330*(10); *90–351*(11); *90–448*(16); *90–460*(17); *90–652*(28). Circumpolar, high-arctic-alpine; previously known from near Clinton Point.

Carex nardina Fries, *90–074b, 90–144*(2); *90–187*(3); *90–209*(4). Amphi-Atlantic, arctic; previously known in the area from a site near Clinton Point.

Carex petricosa Dew., *90–077*(2); *90–328*(10); *90–663*(29); *90–735*(36). Cordilleran, north to the Arctic Coast, Yukon and Alaska; previously known in the area from south of Darnley Bay.

Carex rariflora (Wahlenb.) Sm., *90–491*(20); *90–530*(23). Circumpolar, low-arctic.

Carex saxatilis L., *90–331*(10). Eastern North America, arctic-subarctic; an extension of the known range northwestward some 150 km from Coppermine.

Carex scirpoidea Michx., *90–089, 90–090*(2); *90–180, 90–183a, 90–186*(3); *90–208*(4); *90–224*(5); *90–300*(9); *90–594*(26); *90–630*(27). Wide-ranging North American; previously known in the area from south of Darnley Bay.

Carex subspathacea Wormskj., *90–529, 90–534, 90–537*(23); *90–711*(32). Circumpolar, high-arctic, littoral.

Carex ursina Dewey, *90–532*(23). Circumpolar, high-arctic; previously known in the area from a site near Clinton Point.

Carex vaginata Tausch., *90–092*(2); *90–365*(12). Circumpolar-boreal.

Eriophorum angustifolium Honckn., Cotton-Grass, *90–094, 90–095, 90–096*(2); *90–192*(3); *90–289*(8); *90–303*(9); *90–478, 90–479, 90–480*(19); *90–634, 90–635*(27). Circumpolar, low-arctic-boreal; previously known from near Clinton Point and Darnley Bay.

Eriophorum callitrix Cham., *90–139*(2). Circumpolar, with large gaps, arctic-alpine; previously known from near Clinton Point.

Eriophorum scheuchzeri Hoppe, *90–304, 90–305, 90–306*(9); *90–492*(20); *90–633*(27); *90–653*(28); *90–664*(29). Circumpolar, arctic-alpine; previously known from sites near Darnley Bay and Clinton Point.

Eriophorum triste (Th.Fr.) Hadac & Löve, *90–093*(2); *90–493*(20); *90–508*(21); *90–596*(26). Circumpolar, arctic.

Eriophorum vaginatum L. s.lat., *90–509*(21). Circumpolar, low-arctic-boreal.

Kobresia myosuroides (Vill.) Fiori & Paol., *90–088, 90–143*(2); *90–182*(3); *90–288*(8). Circumpolar; previously known in the area from Darnley Bay and near Clinton Point.

Kobresia simpliciuscula (Wahlenb.) Mack., *90–086*(2). Circumpolar, arctic-alpine; previously known in the area from a site near Clinton Point.

Scirpus caespitosus L. ssp. *austriacus* (Pallas) Asch. & Graebn., Bulrush, *90–481*(19); *90–598*(26). Circumpolar, low-arctic-boreal.

JUNCACEAE

Juncus albescens (Lange) Fern., Bog-Rush, *90–141*(2); *90–188*(3); *90–332, 90–333, 90–334*(10);

90–539(23). North American, arctic-alpine; previously known in the area from near Clinton Point.

Juncus arcticus Willd., *90–140*(2). Amphi-Atlantic, low-arctic; a northwestward extension of some 550 km from Bathurst Inlet.

Juncus balticus L. var. *alaskanus* (Hultén) Porsild, *90–011*(1); *90–395*(14); *90–637*(27); *90–712*(32). Amphi-Beringian, arctic-alpine.

Juncus biglumis L., *90–183b*(3); *90–301, 90–302*(9); *90–576*(24); *90–586*(25). Circumpolar, high-arctic-alpine; previously known from the vicinity of Clinton Point.

Juncus castaneus Smith, *90–142*(2); *90–189*(3); *90–396, 90–397*(14). Circumpolar, arctic-alpine; previously known in the area from Clinton Point.

Luzula confusa Lindebl., Wood-Rush, *90–595, 90–597*(26); *90–721*(33). Circumpolar, arctic-alpine.

Luzula nivalis (Laest.) Beurl., *90–575*(24); *90–746*(40). Circumpolar, high-arctic; previously known in the area from near Clinton Point.

LILIACEAE

Tofieldia coccinea Richards., False Asphodel, *90–407*(14); *90–439*(15). East Greenland to central East Asia.

Tofieldia pusilla (Michx.) Pers., False Asphodel, *90–118*(2); *90–344*(10). Circumpolar, arctic-alpine; previously known from the central part of the area.

Zygadenus elegans Pursh, Death-Camass, *90–550*(23); *90–647*(27). Alaska to southern Manitoba; at the northeastern known limit of known distribution in the District of Mackenzie.

ORCHIDACEAE

Corallorhiza trifida Chat. Coral-root, *90–744* (36). Circumpolar-boreal.

Habenaria obtusata (Pursh) Richards., Northern Bog-Orchid, *90–766*(41). Boreal North America.

SALICACEAE

Salix alaxensis (Anders.) Cov., Willow, *90–097, 90–100*(2). Amphi-Beringian.

Salix arctica Pall., *90–014, 90–016*(1); *90–098, 90–102, 90–103, 90–104*(2); *90–309*(9); *90–400*(14); *90–545*(23); *90–639, 90–640*(27). Circumpolar, arctic-alpine; previously known in the area from near Clinton Point.

Salix brachycarpa L. ssp. *niphoclada* (Rydb.) Argus (*S. niphoclada* Rydb.), *90–018*(1); *90–101, 90–105*(2); *90–193*(3); *90–254, 90–255, 90–256, 90–257*(7); *90–601*(26); *90–638*(27); *90–666*(29); *90–713*(32). North America, Alaska to Hudson Bay, subarctic-alpine; previously known from a site near Clinton Point.

Salix glauca L. s.lat., *90–015, 90–017*(1); *90–335*(10); *90–599, 90–600*(26); *90–674, 90–675*(30). Circumpolar.

Salix hastata L. (*S. farrae* Ball), *90–760, 90–761*(41). Nearly circumpolar; these collections extend the known range in northern District of Mackenzie eastwards some 200 km from about longitude 128°W.

Salix lanata L. ssp. *richardsonii* (Hook.) A. Skvortsov, *90–099*(2); *90–654, 90–655*(28); *90–667*(29); *90–673*(30); *90–762*(41). Amphi-Beringian, low-arctic.

Salix phlebophylla Anders., *90–577*(24). Amphi-Beringian, arctic-alpine; an extension of the known range eastward from near Tuktoyaktuk of some 275 km.

Salix planifolia Pursh, *90–546*(23); *90–714, 90–715*(32). North American, boreal; an extension of the known range northward from the east end of Great Bear Lake of some 175 km.

Salix polaris Wahlenb., *90–310*(9); *90–336*(10); *90–353*(11); *90–513*(21). Amphi-Beringian; an extension of the known range eastwards in northern District of Mackenzie from the Mackenzie River Delta but known from Banks, Victoria and Melville islands to the north.

Salix reticulata L., *90–019*(1); *90–106*(2). Circumpolar, arctic-alpine; previously known in the area from near Clinton Point.

BETULACEAE

Betula glandulosa Michx., Ground or Dwarf Birch, *90–266*(7); *90–367*(12). North America, boreal, sub-arctic.

POLYGONACEAE

Oxyria digyna (L.) Hill, Mountain Sorrel, *90–052*(1); *90–240*(5). Circumpolar, arctic-alpine; previously known in the area from sites near Clinton Point.

Polygonum viviparum L., Bistort, *90–046, 90–047*(1); *90–167*(2); *90–412*(14); *90–658*(28). Circumpolar, arctic-alpine.

Rumex arcticus Trautv., Arctic Dock, *90–120*(2). Amphi-Beringian.

CHENOPODIACEAE

Suaeda calceoliformis (Hook.) Moq., Sea-Blite, *90–552*(23). North American, boreal.

CARYOPHYLLACEAE

Arenaria humifusa Wahlenb., *90–341*(10); *90–402*(14); *90–559*(23). Amphi-Atlantic, arctic-alpine extending westward to Alaska; previously known in the area from near Clinton Point.

Cerastium beeringianum C. & S., *90–461*(17); *90–644*(27). Newfoundland to northeastern Asia, arctic-alpine.

Cerastium regelii Ostenf., *90–227*(5); *90–376*(13); *90–401a*(14); *90–430*(15); *90–730*(35). Circumpolar, high-arctic; previously known from the

Continental Northwest Territories only from the Tuktoyaktuk Peninsula at 70°02'N 129°29'W (Owen & Larsen 74-4227 DAO).

Honkenya peploides L. var. *diffusa* Hornem., Seabeach-Sandwort, *90–422*(14). Circumpolar, low-arctic; previously known from the vicinity of Clinton Point.

Minuartia biflora (L.) Schinzl & Thell., *90–403*(14); *90–751*(40). Circumpolar, low-arctic.

Minuartia rossii (R.Br.) Graebn., *90–127*(2); *90–319*(9); *90–404*(14); *90–590*(25); *90–729*(35); *90–736a*(36). North American, high-arctic.

Minuartia stricta (Sw.) Hiern, *90–642*(27). Circumpolar, arctic-alpine.

Minuartia rubella (Wahlenb.) Hiern, Northern Sandwort, *90–128, 90–129, 90–130*(2); *90–318*(9); *90–340*(10); *90–497*(20); *90–606*(26); *90–690*(30); *90–725*(34). Circumpolar, arctic-alpine; previously known in the area from sites near Clinton Point.

Silene acaulis L. s.lat., Moss Campion, *90–163*(2); *90–214*(4); *90–237*(5). Circumpolar, arctic-alpine; previously known in the area from a site near Clinton Point.

Silene involucrata (C. & S.) Bocquet (*Melandrium affine* J. Vahl), *90–116*(2); *90–563*(23); *90–738*(36). Circumpolar, arctic-alpine.

Silene uralensis (Rupr.) Bocquet (*Melandrium apetalum* ssp. *arcticum sensu* Porsild and Cody (1980)), Bladder-Campion, *90–117*(2); *90–212*(4); *90–294*(8); *90–379*(13); *90–410*(14); *90–706*(31). Circumpolar, high-arctic.

Stellaria humifusa Rottb., *90–547, 90–548, 90–549, 90–565b*(23). Circumpolar, littoral.

Stellaria longipes Goldie s.lat. (incl. *S. laeta* Richards. and *S. monantha* Hultén), Long-stalked Starwort, *90–020*(1); *90–131*(2); *90–226*(5); *90–258, 90–259*(7); *90–354*(11); *90–375*(13); *90–401b*(14); *90–462*(17); *90–605*(26); *90–641*(27); *90–705*(31); *90–750*(40). Circumpolar.

RANUNCULACEAE

Anemone parviflora Michx., Anemone, *90–024, 90–025*(1); *90–197*(3); *90–228*(5); *90–414*(14); *90–471*(18); *90–739*(36). Newfoundland to East Asia, subarctic; previously known in the area from the vicinity of Clinton Point.

Anemone richardsonii Hook., *90–429*(15); *90–764, 90–765*(41). Greenland to East Asia, subarctic.

Caltha palustris L. var. *arctica* (R.Br.) Huth., Marsh-marigold, *90–566*(23). East Asia and arctic northwest America.

Ranunculus aquatilis L. s.lat., White Water-Buttercup, *90–495*(20). Circumpolar, boreal arctic-subarctic.

Ranunculus cymbalaria Pursh, Northern Seaside Buttercup, *90–564*(23). Circumpolar-boreal, with large gaps.

Ranunculus gmelinii DC., *90–158*(2). Hudson Bay to Eurasia.

Ranunculus hyperboreus Rottb., *90–320*(9); *90–435a*(15). Circumpolar, arctic-alpine.

Ranunculus nivalis L., Snow-Buttercup, *90–578*(24). Circumpolar, arctic.

Ranunculus pedatifidus Sm., *90–196*(3); *90–229*(5); *90–292*(8); *90–643*(27). Circumpolar, arctic-alpine; previously known from a site near Clinton Point.

Ranunculus pygmaeus Wahl., Dwarf Buttercup, *90–437*(15); *90–502*(20). Circumpolar, arctic-alpine.

PAPAVERACEAE

Papaver cornwallisensis A. Löve, Poppy, *90–503*(20). North American, arctic-alpine; not previously recorded from the northern parts of the District of Mackenzie; closely related to the circumpolar arctic-alpine *P. radicatum* Rottb.

Papaver macounii Greene (*P. keelei* Porsild), *90–293*(8); *90–380*(13); *90–467*(17); *90–558*(23); *90–612*(26); *90–724*(34). Amphi-Beringian?, arctic-alpine; an extension of the known range eastward in the District of Mackenzie from the Richardson Mountains but also known from the west side of Banks Island to the north.

CRUCIFERAE

Braya glabella Richards., *90–150*(2); *90–215, 90–216*(4); *90–291*(8); *90–692*(30). Endemic to northwest North America.

Braya humilis (C.A. Mey.) Robins. s.lat., *90–037*(1); *90–260*(7); *90–339*(10); *90–433*(15); *90–449*(16); *90–562*(23); *90–649*(27). North America, arctic-alpine; previously known from a site near Clinton Point.

Braya purpurascens (R.Br.) Bunge, *90–217*(4); *90–290*(8); *90–316*(9); *90–416*(14); *90–511*(21); *90–587*(25); *90–668*(29); *90–734*(35). Circumpolar, high-arctic.

Cardamine digitata Richards., *90–147a*(2); *90–313*(9). Northwestern North America, eastern Asia endemic.

Cardamine pratensis L. ssp. *angustifolia* (Hook.) O.E. Schulz, *90–147b*(2); *90–195*(3); *90–230*(5); *90–311*(9); *90–656*(28). Circumpolar, arctic and subarctic.

Cochlearia officinalis L. s.lat., Scurvy-Grass, *90–417, 90–418*(14); *90–709*(31). Circumpolar, littoral.

Descurainia sophioides (Fisch.) O.E. Schulz, Northern Tansy Mustard, *90–035*(1); *90–135*(2). Amphi-Beringian, arctic and subarctic.

Draba alpina L., Alpine Rockcress, *90–151*(2); *90–231*(5); *90–314, 90–317*(9); *90–421*(14); *90–435, 90–436*(15); *90–463*(17); *90–482*(19); *90–499*(20); *90–512*(21); *90–517*(22); *90–731*(35). Circumpolar, high-arctic, alpine.

Draba cinerea Adams, *90–134, 90–138*(2); *90–262, 90–263*(7); *90–315*(9); *90–366*(12); *90–378*(13); *90–431, 90–434*(15); *90–452*(16); *90–464*(17); *90–516*(22); *90–602, 90–603, 90–608*(26); *90–691*(30); *90–745*(37); *90–757*(40). Circumpolar, arctic-alpine; previously known in the area from a site near Clinton Point.

Draba corymbosa R.Br. ex DC., *90–153, 90–154*(2); *90–338*(10); *90–432*(15); *90–498, 90–500*(20); *90–515*(22); *90–582*(24); *90–588*(25); *90–708*(31); *90–726*(34); *90–732*(35); *90–758*(40). Circumpolar, arctic-alpine.

Draba fladnizensis Wulf., *90–604*(26). Circumpolar, arctic.

Draba glabella Pursh, *90–036*(1); *90–137, 90–148, 90–152*(2); *90–264*(7). Circumpolar, arctic-alpine; previously known in the area from a site south of Darnley Bay.

Draba incerta Payson (det. G.A. Mulligan), *90–261*(7). Northern Cordilleran; this collection represents an extension of the known range to the northeast from the central Mackenzie Mountains of some 700 km.

Draba subcapitata Simm. (det. G.A. Mulligan), *90–420*(14). Amphi-Atlantic, high-arctic; this species which is known from the Canadian Arctic Archipelago is here reported for the first time from the Continental Northwest Territories.

Erysimum inconspicuum (S. Wats.) MacMill., Small-flowered Rocket, *90–768*(41). North America, Newfoundland to Alaska.

Erysimum pallasii (Pursh) Fern., *90–132, 90–133, 90–155*(2); *90–419*(14); *90–727*(34). Circumpolar, high-arctic.

Eutrema edwardsii R.Br., *90–312*(9). Circumpolar, arctic-high-arctic.

Lesquerella arctica (Wormskj.) S. Wats., Arctic Bladderpod, *90–136*(2); *90–265*(7); *90–377*(13); *90–501*(20). Eastern Greenland to Eastern Siberia; previously known in the area from Darnley Bay and a site to the east, and in the southern part.

Parrya arctica R.Br., *90–149*(2); *90–337*(10); *90–355*(11); *90–450, 90–451*(16); *90–589*(25); *90–609*(26); *90–733*(35). Endemic to the Canadian Arctic Archipelago south to Great Bear Lake and west to northern Yukon; previously known in the area from a site near Clinton Point.

SAXIFRAGACEAE

Chrysosplenium tetrandrum (Lund) Fries, Golden Saxifrage, *90–246*(5). Circumpolar, arctic-alpine.

Parnassia kotzebuei C. & S., *90–051*(1); *90–343*(10); *90–561*(23); *90–646*(27). West Greenland to Eastern Asia, low arctic-alpine.

Parnassia palustris L. var. *neogaea* Fern., Grass-of-Parnassus, *90–613*(26); *90–719*(32). Boreal North America from Labrador to Alaska.

Saxifraga aizoides L., Yellow Mountain Saxifrage, *90–159*(2); *90–345*(10). Amphi-Atlantic, arctic-alpine; previously known in the area from near Clinton Point.

Saxifraga caespitosa L. s.lat., Tufted Saxifrage, *90–161*(2); *90–415*(14); *90–519*(22); *90–697*(30); *90–753, 90–754*(40). Circumpolar, arctic-high-arctic-alpine; previously known in the area from near Clinton Point.

Saxifraga cernua L., Nodding Saxifrage, *90–236*(5). Circumpolar, arctic-alpine.

Saxifraga foliolosa R.Br., *90–584*(24). Circumpolar, high-arctic.

Saxifraga hirculus L. s.lat., Yellow Marsh Saxifrage, *90–160*(2). Circumpolar, arctic-alpine; previously known in the area from near Clinton Point.

Saxifraga nivalis L., Alpine Saxifrage, *90–441*(15); *90–466*(17); *90–755*(40). Circumpolar, arctic; previously known in the area from near Clinton Point.

Saxifraga oppositifolia L., Purple Saxifrage, *90–034*(1). Circumpolar, arctic-alpine; previously known in our area from several locations including Clinton Point and Darnley Bay.

Saxifraga rivularis L. s.lat., Brook Saxifrage, *90–322*(9); *90–442, 90–443*(15); *90–756*(40). Circumpolar, arctic-alpine.

Saxifraga tricuspidata Rottb., Prickly Saxifrage, *90–162*(2); *90–614*(26). Circumpolar, arctic-alpine; previously known in the area from near Clinton Point.

ROSACEAE

Dryas integrifolia M. Vahl, Mountain Avens, *90–111*(2); *90–321*(9); *90–474*(18). North American, arctic-alpine; previously known in the area from several localities, including Darnley Bay and Clinton Point.

Dryas sylvatica (Hultén) Porsild, *90–031*(1); *90–752*(40). Endemic of central Alaska to western District of Mackenzie.

Potentilla biflora Willd., Two-flower Cinquefoil, *90–356*(11); *90–615*(26); *90–648*(27); *90–698*(30); *90–740*(36). Amphi-Beringian, arctic-alpine; an eastward extension of the known range from the Richardson and Mackenzie Mountains; the Kent Peninsula locality shown in Porsild and Cody (1980) was questionable but is more acceptable now that the species is known from the Melville Hills area.

Potentilla egedii Wormsjk., *90–568*(23). Circumpolar, halophytic.

Potentilla fruticosa L. ssp. *floribunda* (Pursh) Elkington, Shrubby Cinquefoil, *90–0221*(1); *90–269*(7). Nearly circumpolar, boreal.

Potentilla hyparctica Malte var. *elatior* (Abrom.) Fern., Arctic Cinquefoil, *90–580, 90–581*(24). Circumpolar, arctic.

Potentilla nivea L. var. *nipharga* (Rydb.) Sojak (*P. nivea* L. ssp. *hookeriana* (Lehm.) Hiit.), Snow Cinquefoil, *90–023*(1); *90–107, 90–108, 90–109, 90–110*(2); *90–201*(3); *90–211*(4); *90–234a; 90–235*(5); *90–267, 90–270*(7); *90–472, 90–473*(18); *90–607*(26); *90–771*(41). Northwest North America, arctic-alpine.

Potentilla palustris (L.) Scop., Marsh Cinquefoil, *90–370*(12). Circumpolar, boreal.

Potentilla prostrata Rottb. ssp. *prostrata* (*P. nivea* auct. non L.), *90–268*(7). Circumpolar, arctic.

Potentilla rubricaulis Lehmann (*P. rubricaulis* sensu Porsild & Cody pro parte), *90–021*(1); *90–234b*(5); *90–707*(31). Northern North America, endemic; extends the known distribution northward from Great Bear Lake.

Potentilla vahliana Lehm., *90–405*(14). Endemic to the North American Arctic Archipelago and adjacent mainland; previously known in the area from near Clinton Point.

LEGUMINOSAE

Astragalus alpinus L., Alpine Milk-Vetch, *90–030*(1); *90–273*(7); *90–413*(14); *90–453*(16); *90–670*(29); *90–695, 90–696*(30). Circumpolar, arctic-subarctic, alpine.

Astragalus eucosmus Robins., *90–357*(11). North American, boreal.

Hedysarum alpinum L. var. *americanum* Michx., Liquorice-Root, *90–026, 90–029*(1); *90–295*(8); *90–358*(11). North American, Newfoundland to Alaska; previously known in the area near Clinton Point.

Hedysarum mackenzii Richards., *90–027*(1); *90–112*(2); *90–199*(3); *90–272*(7). North America, Newfoundland to Alaska, arctic-subarctic; previously known in the area from near Clinton Point.

Lupinus arcticus S. Wats., Lupine, *90–271*(7). Northwest America, arctic-alpine endemic.

Oxytropis arctica R.Br., Arctic Oxytrope, *90–233*(5); *90–247*(6); *90–275*(7). Arctic North America, endemic.

Oxytropis arctobia Bunge, *90–198*(3); *90–248*(6); *90–454*(16); *90–772*(41). Endemic to North American Arctic Archipelago and adjacent mainland; previously known in our area from near Clinton Point.

Oxytropis deflexa (Pall.) DC. var. *foliolosa* (Hook.) Barneby, *90–200*(3). North American, subarctic-alpine endemic.

Oxytropis maydelliana Trautv. ssp. *melanocephala* (Hook.) Porsild, *90–579*(24). Eastern arctic, North America endemic.

Oxytropis varians (Rydb.) K. Schum, *90–028*(1); *90–113*(2); *90–218*(4); *90–274*(7); *90–570*(23). Northwestern North America endemic; an extension of the known range of some 175 km northward from the east end of Great Bear Lake.

LINACEAE

Linum lewisii Pursh, Flax, *90–485*(19). North America from Ontario to northern Alaska.

EMPETRACEAE

Empetrum nigrum L. var. *hermaphroditum* (Lge.) Böcher, Crowberry, *90–368*(12); *90–565a*(23); *90–611*(26). Circumpolar, boreal-arctic.

ELAEAGNACEAE

Shepherdia canadensis (L.) Nutt., Soapberry, *90–689*(30); *90–763*(41). North America, Newfoundland to Alaska, boreal; previously known from just outside the area, west of site 41.

ONAGRACEAE

Epilobium angustifolium L., Fireweed, *90–050*(1); *90–567*(23). Circumpolar-boreal.

Epilobium latifolium L., Broad-leaved Willowherb, *90–049*(1); *90–115*(2). Circumpolar, arctic-alpine; previously known from sites adjacent to Clinton Point.

HALORAGACEAE

Hippuris vulgaris L., Mare's Tail, *90–122*(2); *90–342*(10); *90–496*(20); *90–540*(23). Circumpolar, boreal-arctic; previously known in the area from near Clinton Point.

PYROLACEAE

Pyrola grandiflora Radius, Large-flowered Wintergreen, *90–238*(5); *90–276*(7); *90–770*(41). Circumpolar, arctic-alpine; previously known in the area from the vicinity of Clinton Point.

Pyrola secunda L. s.lat., One-sided Wintergreen, *90–114*(2); *90–239*(5); *90–769*(41). Circumpolar, boreal.

ERICACEAE

Andromeda polifolia L., Andromeda, *90–279*(7). Circumpolar, boreal.

Arctostaphylos rubra (Rehd. & Wils.) Fern., *90–123*(2); *90–278*(7); *90–569*(23); *90–659*(28). North American-Eastern Asia; previously known in the area from a site near Clinton Point.

Cassiope tetragona (L.) D. Don, Arctic White Heather, *90–156, 90–157*(2); *90–232*(5). Circumpolar, arctic; previously known in the area from a site near Clinton Point.

Ledum decumbens (Ait.) Lodd., Northern Labrador-tea, *90–372*(12). Amphi-Beringian; previously known in the area from a site near Clinton Point.

Rhododendron lapponicum (L.) Wahlenb., Lapland Rose-bay, *90–125*(2). Circumpolar, arctic-alpine; previously known in the area from "Fraser" Lake.

Vaccinium uliginosum L. s.lat., Bilberry, *90–124*(2). Circumpolar, boreal-arctic; previously known in the area from a site near Clinton Point.

Vaccinium vitis-idaea L. var. *minus* Lodd., Mountain Cranberry, *90–373*(12); *90–583*(24). Circumpolar, arctic-boreal.

PRIMULACEAE

Androsace chamaejasme Host. var. *arctica* Knuth, Rock-Jasmine, *90–032*(1); *90–126*(2). Amphi-Beringian; previously known in the area from sites near Clinton Point and southward.

Androsace septentrionalis L., *90–406*(14). Circumpolar, boreal-arctic.

Primula egaliksensis Wormsk., *90–718*(32). North America from Labrador and West Greenland to Alaska.

Primula stricta Hornem., *90–555*(23). Amphi-Atlantic extending westwards to Alaska.

PLUMBAGINACEAE

Armeria maritima (Mill.) Willd. ssp. *labradorica* (Wallr.) Hultén, Thrift, *90–048*(1); *90–121*(2). Amphi-Atlantic, extending westwards to the Mackenzie River Delta and Mackenzie Mountains, boreal-arctic; previously known in the area from sites near Clinton Point and southward.

GENTIANACEAE

Gentianella propinqua (Richards.) J.M. Gillett ssp. *propinqua* (*Gentiana propinqua* Richards.), *90–044*(1); *90–225*(5); *90–411*(14); *90–438*(15); *90–556*(23); *90–645*(27). Newfoundland to Alaska and Northeast Asia, arctic-alpine; previously known in the area from near Clinton Point.

Gentiana prostrata Haenke, Moss Gentian, *90–767*(41). Amphi-Beringian, alpine; an extension of the known range eastward some 550 km from sites in the Richardson mountains.

Gentianopsis detonsa (Rottb.) Ma ssp. *detonsa* (*Gentiana detonsa* Rottb. ssp. *detonsa; G. richardsonii* Porsild), *90–042*(1); *90–553*(23). Circumpolar, with many large gaps.

Lomatogonium rotatum (L.) Fries, Marsh Felwort, *90–041*(1); *90–554*(23). Circumpolar, subarctic-arctic.

POLEMONIACEAE

Phlox richardsonii Hook., *90–045*(1); *90–408*(14). Endemic to northern Alaska, Yukon Territory, District of Mackenzie and Banks Island; previously known in the area from Darnley Bay.

BORAGINACEAE

Mertensia drummondii (Lehm.) G. Don, *90–409*(14). Endemic to the Arctic Coast of District of Mackenzie, southern Victoria Island and northwestern Alaska; an extension of the known range in northern District of Mackenzie about 80 km westward from Cape Young.

SCROPHULARIACEAE

Castilleja caudata (Pennell) Rebr., Indian Paintbrush, *90–687, 90–688*(30). Amphi-Beringian, alpine-subarctic.

Castilleja elegans Malte, *90–040*(1); *90–203*(3); *90–560*(23); *90–669*(29). Arctic North America from Hudson Bay to northern Alaska, disjunct to Rocky Mountains of Alberta; previously known in the area from Darnley Bay.

Castilleja hyperborea Pennell, *90–039*(1); *90–164*(2); *90–483*(19). Amphi-Beringian; an extension of the known range south eastwards from Cape Perry of some 250 km.

Pedicularis arctica R.Br., *90–202*(3); *90–241*(5). Arctic and alpine North America.

Pedicularis capitata Adams, *90–033*(1); *90–166*(2); *90–346*(11). Circumpolar, arctic-alpine; previously known in the area from near Clinton Point.

Pedicularis flammea L., *90–455*(16); *90–484*(19). Amphi-Atlantic, arctic-alpine; a northward extension of the known range of some 250 km from the north shore of Great Bear Lake.

Pedicularis lanata C. & S., Woolly Lousewort, *90–038*(1); *90–249*(6); *90–323*(9). North American, arctic-alpine; previously known in the area from near Clinton Point.

Pedicularis sudetica Willd., *90–165*(2); *90–371*(12); *90–504*(20). Circumpolar, arctic-alpine; previously known in the area from "Fraser" Lake.

LENTIBULARIACEAE

Pinguicula vulgaris L., Butterwort, *90–277*(7); *90–360*(11); *90–657*(28). Circumpolar, subarctic-alpine; previously known in the area from Darnley Bay.

PLANTAGINACEAE

Plantago canescens Adams, *90–551*(23). Amphi-Beringian.

Plantago maritima L. ssp. *juncoides* (Lam.) Hultén (*P. juncoides* var. *glauca* sensu Porsild & Cody (1980)), Seaside Plantain, *90–557*(23). North American halophyte; a northwestward extension of the known range of some 250 km from eastern Great Bear Lake. The map in Hultén (1968) indicates a site in the Mackenzie River Delta. This site was also shown on the map in Harms et al. (1986) with a question mark, but was omitted by Porsild and Cody (1980) because it could not be confirmed. The presence of this taxon on the Arctic Coast does however support the possibility of its occurence in the Mackenzie River Delta.

CAMPANULACEAE

Campanula uniflora L., Arctic Harebell, *90–043*(1); *90–119*(2); *90–213*(4); *90–359*(11); *90–693*(30). Circumpolar, high arctic-alpine; previously known in the area from near Clinton Point and "Fraser" Lake.

COMPOSITAE

Achillea nigrescens (E. Mey.) Rydb., Everlasting, *90–574*(23). North America, boreal-arctic.

Antennaria angustata Greene, *90–204*(3); *90–324*(9); *90–619*(26); *90–741*(36). North America, arctic-subarctic-alpine; previously known in the area from near Clinton Point.

Antennaria compacta Greene, *90–059*(1); *90–168*(2); *90–194*(3); *90–252*(6); *90–374*(12); *90–618*(26). North America, high-arctic; previously known in the area from near Clinton Point. The type locality is Bernard Harbour (114°46'W).

Antennaria friesiana (Trautv.) Ekman s.lat. (*A. ekmaniana* Porsild), *90–169*(2); *90–205*(3); *90–243*(5); *90–296*(8); *90–445*(15); *90–742*(36). North America, arctic-alpine; helps complete the known distribution in northern District of Mackenzie between Cape Dalhousie and Coppermine.

Arnica angustifolia J. Vahl ssp. *angustifolia* (A. *alpina* (L.) Olin ssp. *angustifolia* (J. Vahl) Maguire), Alpine Arnica, *90–206, 90–207*(3); *90–280*(7); *90–361*(11); *90–456*(16). North America, arctic-alpine; previously known in the area from near Clinton Point. An up-to-date map of the known distribution is presented in Downie (1988).

Arnica griscomii Fern. ssp. *frigida* (Meyer ex Iljin) S.J. Wolf (*A. louiseana* Farr. ssp. *frigida* (Meyer ex Iljin) Maguire, *90–362*(11). Amphi-Beringian, arctic-alpine; previously known in the area from near Clinton Point.

Artemisia borealis Pall., Wormwood, *90–056*(1); *90–177*(2); *90–219*(4); *90–253a*(6); *90–347*(10). Circumpolar, sub-arctic.

Artemisia hyperborea Rydb., *90–057*(1); *90–245*(5); *90–253b*(6). Endemic to northwestern District of Mackenzie and the southwestern Arctic Islands.

Artemisia tilesii Ledeb., *90–381*(13); *90–774*(41). Amphi-Beringian, arctic-subarctic.

Aster pygmaeus Lindl., *90–173*(2); *90–446*(15); *90–661*(28). Endemic to the southwestern Arctic Islands and adjacent mainland.

Aster sibiricus L., *90–054*(1); *90–457*(16); *90–660*(28); *90–671*(29); *90–701*(30); *90–773*(41). Amphi-Beringian.

Chrysanthemum arcticum L., Arctic Daisy, *90–573*(23). Circumpolar, low-arctic; an extension of the known range in northern District of Mackenzie eastwards some 200 km from Liverpool Bay and then disjunct to the shores of Hudson Bay.

Chrysanthemum integrifolium Richards., *90–174*(2); *90–702*(30). North America, arctic-alpine; previously known in the area from near Clinton Point and "Fraser" Lake.

Crepis nana Richards., Dwarf Hawk's-beard, *90–458*(16). Nearly circumpolar, with large gaps, arctic-alpine.

Erigeron compositus Pursh, *90–251*(6); *90–283*(7); *90–425*(14). North American, arctic-alpine.

Erigeron eriocephalus J. Vahl, *90–171*(2); *90–349*(10); *90–728*(34). Circumpolar, arctic-alpine.

Erigeron humilis Grah., *90–053*(1); *90–170, 90–172*(2); *90–281*(7); *90–348*(10); *90–382*(13); *90–423, 90–424*(14); *90–616*(26); *90–743*(36). Circumpolar, arctic-alpine; previously known in the area from sites at Darnley Bay and near Clinton Point.

Senecio atropurpureus (Ledeb.) Fedtsch., *90–175*(2); *90–325*(9); *90–585*(24); *90–591*(25); *90–775*(41). Amphi-Beringian, arctic-alpine; previously known in the area from Darnley Bay and "Fraser" Lake.

Senecio hyperborealis Greenm., Northern Groundsel, *90–426*(14); *90–720*(32). Endemic to northwestern North America, alpine-arctic-subarctic; previously known in the area from a site southeast of Darnley Bay.

Senecio lugens Richards., *90–058*(1); *90–176*(2); *90–244*(5). Western North America; previously known in the area from Darnley Bay and near Clinton Point.

Solidago multiradiata Ait., Northern Goldenrod, *90–220*(4); *90–282*(7); *90–363*(11); *90–487*(19); *90–620*(26); *90–672*(29); *90–699*(30). North America, Newfoundland to British Columbia and Alaska; previously known in the area from near Clinton Point.

Taraxacum alaskanum Rydb., Dandelion, *90–350*(10); *90–383*(13); *90–459*(16); *90–469*(17); *90–505*(20); *90–617*(26); *90–722*(33). Northwestern North America, arctic-alpine; an extension of the known distribution eastwards from Franklin Bay of some 250 km.

Taraxacum dumetorum Greene, *90–055*(1); *90–571*(23); *90–700*(30). Western North America; an extension of the known distribution in northern District of Mackenzie eastwards from Liverpool Bay of some 320 km.

Taraxacum pumilum Dahlst., *90–242*(5); *90–447*(15); *90–572*(23). Endemic to the Canadian Arctic Archipelago and adjacent mainland.

Acknowledgments

The authors gratefully acknowledge the support of Polar Continental Shelf Project, Energy, Mines and Resources Canada in making a helicopter available for the survey of the Melville Hills area, and the Canadian Parks Service for logistics. The manuscript

maps of Erling Porsild which have proven so useful were presented to Cody by Porsild's daughter, Mrs. Karin Lumsden and are gratefully acknowledged. Comments on an earlier draft of the manuscript by J. Cayouette and E. Small, Biosystematics Research Centre, Agriculture Canada, were much appreciated.

Literature Cited

Aiken, S. G., and **S. J. Darbyshire**. 1990. Fescue Grasses of Canada. Agriculture Canada Publication 1844/E. 113 pages.

Aiken, S. G., and **L. P. Lefkovitch**. 1990. *Arctagrostis* (Poaceae, tribe Pooideae) in North America and Greenland. Canadian Journal of Botany 68: 2422–2432.

Craig, B. G. 1960. Surficial geology of north-central District of Mackenzie, Northwest Territories. Geological Survey of Canada. Paper 60–18.

Downie, S. R. 1988. Morphological, cytological and flavonoid variability of *Arnica angustifolia* aggregate (Asteraceae). Canadian Journal of Botany 66: 24–39.

Dyke, A. S., and **V. K. Prest.** 1987. Late Wisconsin and Holocene retreat of the Laurentide Ice Sheet. Geological Survey of Canada, Map 1702A.

Environment Canada. 1982. Canadian climate normals. Volume 2, Temperature; Volume 3, Precipitation; Volume 4, Degree Days. Atmospheric Environment Service, Downsview, Ontario.

Harms, V. L., D. F. Hooper, and **L. Baker**. 1986. *Plantago maritima* and *Carex mackenzei* new for Saskatchewan: additional rare inland stations for two seacoast salt marsh species. Rhodora 88: 315–323.

Porsild, A. E., and **W. J. Cody.** 1980. Vascular plants of Continental Northwest Territories, Canada. National Museums of Canada, Ottawa. 667 pages.

Scotter, G. W., and **D. H. Vitt**. 1992. Bryophytes of the Melville Hills Region, Northwest Territories. Canadian Field-Naturalist 106(1): 100–104.

Thomson, J. W., and **G. W. Scotter**. 1992. Lichens of the Cape Parry and Melville Hills Regions, Northwest Territories. Canadian Field-Naturalist 106(1): 105–111.

Welsh, S. L. 1974. Anderson's Flora of Alaska and Adjacent Parts of Canada. Brigham Young University Press. 724 pages.

Received 26 July 1991
Accepted 17 February 1992

Bryophytes of the Melville Hills Region, Northwest Territories

GEORGE W. SCOTTER[1] AND DALE H. VITT[2]

[1]R.R. 4, S9-C15, Kelowna, British Columbia V1Y 7R3
[2]Department of Botany, The University of Alberta, Edmonton, Alberta T6G 2E9

Scotter, George W. and Dale H. Vitt. 1992. Bryophytes of the Melville Hills Region, Northwest Territories. Canadian Field-Naturalist 106(1): 100–104.

One hundred and three species of bryophytes are reported from the Melville Hills region (69°N, 120°W) as a result of field surveys of 22 localities in 1990. The Melville Hills region lies entirely beyond the treeline in the Low Arctic zone of continuous tundra vegetation. A portion of the region was not glaciated during the latest Wisconsinan Glaciation. Range extensions are reported for the following 15 species: *Bryum wrightii, Campylium arcticum, Cinclidium arcticum, C. latifolium, Desmatodon leucostoma, Drepanocladus lycopodioides* var. *brevifolius, Grimmia plagiopodia, Hypnum procerrimum, Schistidium andreaeopsis, S. tenerum, Tetraplodon pallidus, T. paradoxus, Timmia norveqica, T. sibirica,* and *Voitia hyperborea.*

Key Words: Arctic, bryophytes, Melville Hills, mosses, Northwest Territories, tundra.

The Melville Hills are located in the northeastern section of the District of Mackenzie, between longitudes 119°N and 123°N, south of Amundsen Gulf of the Arctic ocean. A natural resource survey of this region was undertaken by the Canadian Wildlife Service and Forestry Canada during 1990, because of the potential of this area as a national park or national wildlife area. The bryophyte flora of this area is virtually unknown, as all previous records were from Coppermine (Steere 1977; Robinson et al. 1989a, 1989b) and Bathurst Inlet (Steere and Scotter 1986) on the east; Great Bear Lake (Steere 1977) on the south; and Cape Parry (Steere and Scotter 1986), Horton River (Robinson et al. 1989a, 1989b), and Reindeer Station (Holmen and Scotter 1971) on the west. The purpose of this paper is to report the bryophytes collected during the 1990 survey.

The study area is centered on the Melville Hills, occupying an area of approximately 33 000 km^2. The Melville Hills rise gradually to a maximum height of 876 m ASL. The hills are drained by the Hornaday River and Brock River towards the west, eroding deep canyons near the coast. Bluenose Lake, a large (400 km^2) lake on the eastern flank of Melville Hills, is drained northward by the Croker River. The hills are largely composed of nearly horizontally bedded Precambrian sandstone, with local basaltic intrusive rocks. Poorly consolidated sedimentary rocks of Cretaceous age occur on the lowlands west of Melville Hills.

The Melville Hills were not glaciated during the latest Wisconsinan Glaciation (Dyke and Prest 1987). Ice flow pattern suggests that the late Wisconsinan glacier ice, advancing from the southeast, was deflected around Melville Hills (Craig 1960). Wood, identified as *Pinus strobus* type (R. Mott, personal communication), was found on the shores of a large lake at the headwaters of the largest tributary of Hornaday River. This wood was dated as >41, 000 yrs by the Geological Survey of Canada (GSC-5115). The central portion of Melville Hills has no glacial erratics, suggesting that perhaps a small portion of the uplands may have totally escaped glaciation. Although the understanding of glacial time sequence of this area requires more study, it seems that the Melville Hills were free of ice for a much longer period of time than the remainder of the neighbouring Arctic mainland.

The climate is characterized by long, cold winters and low amounts of precipitation. At Clinton Point on the Amundsen Gulf coast the mean annual temperature is –11.2°C, and the mean July temperature is 7.4°C (Environment Canada 1982), but frost can occur even during the summer months. The mean cumulative annual degree days above 5° is 203. The mean annual precipitation is 181.5 mm, about half of which (85.0 cm) occurs as snow.

The vegetation is influenced by local elevation and exposure. In the well protected valleys of the lower Hornaday and Brock rivers tall willow shrubs and continuous tundra vegetation occurs. At higher elevations the vegetation cover is discontinuous, with low, ground-hugging shrubs, forbs, and sedges. In general, the wet sites are dominated by sedges and cottongrass, as well as mosses. *Kobresia myosiroides* and *Dryas integrifolia* are the dominant vascular plant species of the upland tundra. *Sphagnum* is rare in the area, with wet tundra sites characterized by brown mosses in the genera *Drepanocladus, Campylium, Cinclidium, Catoscopium,* and *Tomenthypnum*; all species that are common in calcareous arctic tundra and boreal extreme-rich fens. In the exposed bedrock and rock rubble areas crustose and umbilicate lichens dominate, with only scattered dwarf shrubs and mosses. *Tortula, Ceratodon,*

Ditrichum, Schistidium, and *Polytrichum* are common moss genera.

Phytogeographically, the bryophytes can be divided into five groups[1]. The Melville Hills flora consists of 5% cosmopolitan species, 14% widespread species, 35% boreal species, 18% arctic species, and 28% arctic-montane species. The large percentage of species (46%) having the majority of their ranges to the north and northwest suggests that the Melville Hills represents a significant southern extension for these largely arctic or arctic-montane species, while serving as a northerly station for the boreal species that extend northward into the High Arctic.

Site List

In the course of the survey, bryophytes were collected at 22 sites. Those sites were mapped in a paper on the vascular plants of the area (Cody et al. 1992). Latitudes, longitudes and elevations in meters above sea level of the collection sites (given in parentheses) from which specimens are cited in this paper are:

2. "Hornaday Lake", 68° 42'N, 120° 48'W, 513 m, 24 July 1990.
7. Hornaday River, 68° 33'N, 120° 46'W, 490 m, 25 July 1990.
8. 68° 44'N, 121° 03'W, 660 m, 26 July 1990.
9. 68° 39'N, 121° 15'W, 730 m, 26 July 1990.
10. Hornaday River, 68° 36'N, 120° 41'W, 510 m, 26 July 1990.
12. 68° 17'N, 121° 14'W, 510 m, 26 July 1990.
13. Croker River Canyon, 69° 06'N, 119° 30'W, 340 m, 27 July 1990.
14. Croker River Delta, 69° 17'N, 119° 07'W, 2 m, 27 July 1990.
15. "Conglomerate Hill", 69° 21'N, 119° 57'W, 30 m, 27 July 1990.
16. "Diabase Canyon", 69° 17'N, 120° 21'W, 275 m, 27 July 1990.
17. 69° 18'N, 119° 56'W, 180 m, 27 July 1990.
19. 68° 27'N, 121° l0'W, 550 m, 28 July 1990.
21. 69° 47'N, 121° 52'W, 55 m, 2 July 1990.
22. 69° 48'N, 121° 53'W, 2 m, 29 July 1990.
23. Lower Brock Lagoon, 69° 31'N, 123° 13'W, 2 m, 29 July 1990.
24. 69° 08'N, 121° 50'W, 700 m, 29 July 1990.
30. La Roncière Falls, 69° 08'N, 122° 52'W, 215 - 275 m, 31 July 1990.
33. 69° 26'N, 122° 23'W, 430 m, 31 July 1990.
35. 68° 42'N, 121° 31'W, 710 m, 1 August 1990.
36. 68° 46'N, 122° 25'W, 420 m, 1 August 1990.
40. Brock Canyon, 69° 21'N, 122° 48'W, 300 m, 2 August 1990.
41. Lower Brock River, 69° 23'N, 123° 04'W, 60 m, 2 August 1990.

Species List

In the list of bryophytes which follows, the nomenclature and classification essentially follows Stotler and Crandall-Stotler (1977) for hepatics and Ireland et al. (1987) for mosses. All identifications were made by Vitt, with specimens deposited in ALTA (University of Alberta, Edmonton) and the first duplicate set in CANM (Canadian Museum of Nature, Ottawa).

Hepaticopsida

PSEUDOLEPICOLEACEAE

Blepharostoma trichopyllum (L.) Dum. (17, 30).

PTILIDIACEAE

Ptilidium ciliare (L.) Hampe.

PLAGIOCHILACEAE

Plagiochila arctica Bryhn & Kaal. (30).

JUNGERMANNIACEAE

Anastrophyllum minutum (Schreb.) Schust. (12, 24).
Chandonanthus setiformis (Ehrh.) Lindb. (24).
Lophozia binsteadii (Kaal.) Evans (24).
Lophozia rutheana (Limpr.) Howe (8, 12, 21).
Tritomaria quinquedentata (Huds.) Buch (35).

SCAPANIACEAE

Scapania simmonsii Bryhn & Kaal. (40).

ANEURACEAE

Aneura pinguis (L.) Dum. (21).

MARCHANTIACEAE

Marchantia polymorpha L. (9).
Preissia quadrata (Scop.) Nees (7, 19).

Sphagnopsida

SPHANGNACEAE

Sphagnum capillifolium (Ehrh.) Hedw. (12).
Sphagnum russowii Warnst. (12).
Sphagnum teres (Schimp.) C. Hartm. (24).

Bryopsida

POLYTRICHACEAE

Polytrichum alpinum Hedw. (12, 24).
Polytrichum juniperinum Hedw. (12, 24, 33, 35).
Polytrichum strictum Brid. (12, 24).

SPLACHNACEAE

Aplodon wormskjoldii (Hornem.) R.Br. (19).
Splachnum sphaericum Hedw. (16, 21).
Splachnum vasculosum Hedw. (2, 15, 19).
Tetraplodon mnioides (Hedw.) BSG (16, 17, 19, 21, 35).

[1]Widespread: species with a major portion of their range extending southward into the temperate region (e.g., *Pohlia cruda*); boreal: species having their ranges centered in the boreal region, most extend northward into the arctic, with rare extensions into the temperate areas (*Tomenthypnum nitens*); arctic-montane: arctic species with major extensions southward along the western cordillera (*Aulacomnium turgidum*); arctic: species largely restricted to north of the arctic circle (*Voitia hyperborea*).

Tetraplodon pallidus Hag. (17, 19, 21, 24, 30, 35). Known from arctic Alaska, the Yukon Territory, and five localities in the Mackenzie District, Northwest Territories, as well as from northern Greenland and the northeastern Arctic Archipelago (Steere 1978). The present locality is the most northeasterly in western North America.

Tetraplodon paradoxus (R.Br.) Hag. (24). A species of arctic Alaska, known eastward only from the Great Bear Lake area, the Mackenzie Delta area, and one site on Baffin Island (Brassard et al. 1982).

Voitia hyperborea Grev. & Arnott (9, 12, 14, 15, 16, 24). One of the southernmost stations for this arctic species, otherwise known from northern Alaska, the Canadian Arctic Islands, the Horton River, and the Mackenzie Mountains at 65°N latitude (Steere 1978).

ORTHOTRICHACEAE

Orthotrichum anomalum Hedw. (2).

Orthotrichum speciosum Sturm (2, 10, 12, 16, 35).

BRYACEAE

Bryum algovicum C. Muell. (15, 16).

Bryum argenteum Hedw. (7).

Bryum calophyllum R.Br. (9).

Bryum cyclophyllum (Schwaegr.) BSG (21, 22).

Bryum pseudotriquetrum (Hedw.) GMS (7, 9, 12, 16, 19, 21, 23, 36).

Bryum weigelii Spreng. (21).

Bryum wrightii Sull. & Lesq. (2, 10, 33). The second report of this moss from the continental Northwest Territories. Along with Brassard's (1972) record from 127°W longitude, these are some of the few records of this species from continental Northwest Territories.

Leptobryum pyriforme (Hedw.) Wils. (8, 9, 10, 19, 23).

Pohlia cruda (Hedw.) Lindb. (8, 12).

Pohlia nutans (Hedw.) Lindb. (24).

MNIACEAE

Cinclidium arcticum (BSG) Schimp. (2, 8, 9, 12, 16, 19, 21, 33, 36). An arctic species known as far south as southern Baffin Island in the east, and Churchill and the Great Bear Lake – Mackenzie Mountain area in the west. Farther north, it is known from northern Alaska, Banks Island and the Canadian Arctic Islands and Greenland (Steere 1978).

Cinclidium latifolium Lindb. (2, 12, 19, 21). A rare arctic species known, in North America, from northern Alaska, Banks Island, the Churchill Area (Manitoba), Ellesmere Island, Greenland, and on two of the eastern Canadian Arctic Islands. This is the first report of the species from the Mackenzie District (Steere 1978).

Cyrtomnium hymenophylloides (Hueb.) Kop. (12, 30).

Cyrtomnium hymenophyllum (BSG) Holmen (30).

Mnium thomsonii Schimp. (30).

Plagiomnium ellipticum (Brid.) Kop. (19, 41).

Plagiomnium medium (BSG) Kop. (24, 30, 35).

TIMMIACEAE

Timmia megapolitana ssp. *bavarica* (Hessl.) Brass. (15).

Timmia norvegica Zett. (10, 30). This is a widespread arctic species with several disjunct stations in the western cordillera and in Labrador-Newfoundland. This is the first record of the species from the northern coast of continental Northwest Territories, although collections are known from the Yukon, Great Slave Lake, and Banks Island (Brassard 1979).

Timmia sibirica Lindb. & H. Arnell (9). Previously known from northern Alaska, the Yukon Territory, Mackenzie Mountains, Northwest Territories, northern British Columbia, and Alberta in the west, and from Greenland, west to Somerset and Axel Heiberg islands. The present station joins the previously known eastern and western portions of the North American distribution (Horton 1981).

BARTRAMIACEAE

Conostomum tetragonum (Hedw.) Lindb. (24).

Philonotis fontana var. *pumila* (Turn.) Brid. (8, 9, 10, 19, 21, 36).

AULACOMNIACEAE

Aulacomnium acuminatum (Lindb. & H. Arnell) Kindb. (2, 19, 21).

Aulacomnium palustre (Hedw.) Schwaegr. (12, 35, 41).

Aulacomnium turgidum (Wahlenb.) Schwaegr. (1, 12, 21).

MEESIACEAE

Meesia triquetra (Richt.) Aongstr. (2, 8, 12, 19, 21).

Meesia uliginosa Hedw. (12, 21, 24).

CATOSCOPIACEAE

Catoscopium nigritum (Hedw.) Brid. (2, 8, 12, 16, 21, 33, 36).

THUIDIACEAE

Myurella julacea (Schwaegr.) BSG (9, 17).

Myurella tenerrima (Brid.) Lindb. (12).

Pseudoleskeella tectorum (Brid.) Broth. (7, 10).

Thuidium abietinum (Hedw.) BSG (2, 10).

Thuidium recognitum (Hedw.) Lindb. (41).

AMBLYSTEGIACEAE

Calliergon giganteum (Schimp.) Kindb. (8, 9, 36).

Calliergon sarmentosum (Wahlenb.) Kindb. (24).

Calliergon stramineum (Brid.) Kindb. (24).

Calliergon trifarium (Web. & Mohr) Kindb. (8).

Campylium arcticum (Williams) Broth. (7, 12, 21, 36). This species is known from Alaska and the Canadian Arctic. The Melville Hills locality is one of the few Canadian reports from the western Canadian mainland.

Campylium stellatum (Hedw.) C. Jens. (14, 19, 21).
Drepanocladus aduncus (Hedw.) Warnst. (41).
Drepanocladus lycopodioides var. *brevifolius* (Lindb.) Moenk. (2, 8, 9, 19, 21, 22, 24). An arctic species occurring from northern Greenland, Ellesmere Island and northern Alaska south to this locality in the west and Ungava in the east; also known from the Horton River area (Schofield 1972).
Drepanocladus revolvens (Sw.) Warnst. (9, 12, 16, 21, 36).
Drepanocladus uncinatus (Hedw.) Warnst. (2, 10, 17, 30).
Scorpidium scorpioides (Hedw.) Limpr. (8).
Scorpidium turgescens (T. Jens.) Loeske (9, 12, 21).

BRACHYTHECIAEAE
Brachythecium turgidum (C.J. Hartm.) Kindb. (9, 23, 30).
Tomenthypnum nitens (Hedw.) Loeske (2, 8, 9, 12, 24, 35, 41).

HYPNACEAE
Hypnum bambergeri Schimp. (7, 16, 21).
Hypnum procerrimum Mol. (17). Known in North America from scattered localities along the western cordillera south to the U.S. border, northern Alaska, one site near the Horton River, several of the Canadian Arctic Islands, and Newfoundland (Schofield 1980).
Hypnum revolutum (Mitt.) Lindb. (2, 8).
Hypnum vaucheri Lesq. (2).
Orthothecium chryseum (Schultes) BSG (2, 21).
Orthothecium strictum Lor. (16).

HYLOCOMIACEAE
Hylocomium splendens (Hedw.) BSG (12, 24).

ENCALYPTACEAE
Encalypta alpina Sm. (17).
Encalypta rhaptocarpa Schwaegr. (30, 40).

POTTIACEAE
Bryoerythrophyllum recurvirostrum (Hedw.) Chen (2).
Desmatodon leucostoma (R.Br.) Berggr. (15). An arctic-alpine species known in North America from Alaska, the Yukon, the Northwest Territories and Greenland, extending southward through the Rocky Mountains of Alberta to Colorado.
Didymodon asperifolius (Brid.) CSA (8, 10).
Didymodon rigidulus var. *icmadophila* (C. Muell.) Zand. (10).
Gymnostomum aeruginosum Sm. (30).
Tortula norvegica (Web.) Lindb. (36).
Tortula ruralis (Hedw.) GMS (2, 7, 8, 10, 15, 16, 17, 35).

DICRANACEAE
Dicranum elongatum Schwaegr. (12, 19, 24, 35).
Dicranum spadiceum Zett. (12).
Oncophorus wahlenbergii Brid. (2, 12).

DITRICHACEAE
Ceratodon purpureus (Hedw.) Brid. (2, 9, 10, 16, 24, 30, 40).
Distichium capillaceum (Hedw.) BSG (7, 10, 15, 17, 22).
Ditrichum flexicaule (Schwaegr.) Hampe (2, 7, 10, 17, 21, 22, 30).

GRIMMIACEAE
Grimmia anodon BSG (10, 17).
Grimmia plagiopodia Hedw. (8, 10). A species not recently mapped, but according to Ireland et al. (1987), new to continental Northwest Territories. Otherwise in Canada known from Alberta, British Columbia, Saskatchewan and Ontario.
Racomitrium lanuginosum (Hedw.) Brid. (24, 30).
Schistidium andreaeopsis Ochyra & Afonina (10, 17). Ochyra and Afonina (1986) placed *Schistidium holmenianum* Steere & Brass. into synonymy with *S. andreaeopsis*, originally described from Siberian material. In North America, they mapped its occurrence from Greenland and the Canadian Arctic Islands west to the north slope of Alaska. They report the only localities from the continental Northwest Territories, west of Hudson Bay from the Boothia Peninsula and from the Cape Parry region at 124°W longitude. This is the second report from continental Northwest Territories west of the Boothia.
Schistidium apocarpum Hedw. (2, 7, 8, 10, 13, 17, 30, 40).
Schistidium rivulare (Brid.) Podp. (2, 9, 21, 40).
Schistidium tenerum (Zett.) Nyh. (15, 17). Elsewhere known from Greenland, scattered in the western cordillera, north coast of Alaska, Great Bear Lake, and Great Slave Lake (Schofield 1972).

Literature Cited

Brassard, G. R. 1972. Mosses from the Mackenzie Mountains, Northwest Territories. Arctic 25: 308.

Brassard, G. R. 1979. The moss genus *Timmia*. 1. Introduction, and revision of *T. norvegica* and allied taxa. Lindbergia 5: 39–53.

Brassard, G. R., R. J. Belland, and **J. Bridgeland.** 1982. Two rare arctic or montane mosses new to the Canadian Arctic Archipelago. The Bryologist 85: 139–141.

Cody, W. J., G. W. Scotter, and **S. C. Zoltai.** 1992. Vascular plant flora of the Melville Hills Region, Northwest Territories. Canadian Field-Naturalist 106 (1): 87–99.

Craig, B. G. 1960. Surficial geology of north-central District of Mackenzie, Northwest Territories. Geological Survey of Canada. Paper 60–18.

Dyke, A. S., and **V. K. Prest.** 1987. Late Wisconsin and Holocene retreat of the Laurentide Ice Sheet. Geological Survey of Canada, Map 1702A.

Environment Canada. 1982. Canadian climate normals. Volume 2, Temperature; Volume 3, Precipitation; Volume 4, Degree Days. Atmospheric Environment Service, Downsview, Ontario.

Holmen, K., and **G. W. Scotter.** 1971. Mosses of the Reindeer Preserve, Northwest Territories, Canada. Lindbergia 1–2: 34–56.

Horton, D.G. 1981. The taxonomic status of *Timmia sibirica*. Canadian Journal of Botany 59: 563–571.

Ireland, R. R., G. R. Brassard, W. B. Schofield, and **D. H. Vitt.** 1987. Checklist of the mosses of Canada II. Lindbergia 13: 1–62.

Ochyra, R., and **O. M. Afonina.** 1986. The taxonomic position and geographical distribution of *Grimmia andreaeopsis* C. Muell. (Grimmiaceae, Musci). Polish Polar Research 7: 319–332.

Robinson, A. L., D. H. Vitt, and **K. P. Timoney**. 1989a. Patterns of community structure and morphology of bryophytes and lichens related to edaphic gradients in the subarctic forest-tundra of northwestern Canada. The Bryologist 92: 495–512.

Robinson, A. L., D. H Vitt, and **K. P. Timoney**. 1989b. Patterns of bryophyte and lichen distribution in relation to latitudinal and edaphic gradients in the Canadian subarctic forest-tundra. Nova Hedwigia 49: 25–48.

Schofield, W. B. 1972. Bryology in arctic and boreal North America and Greenland. Canadian Journal of Botany 50: 1111–1133.

Schofield, W. B. 1980. Phytogeography of the mosses of North America (North of Mexico). Pages 131–170 *in* The Mosses of North America. *Edited by* R. J. Taylor and A. E. Leviton. Pacific Division, American Association for the Advancement of Science, California.

Steere, W. C. 1977. Bryophytes from Great Bear Lake and Coppermine, Northwest Territories, Canada. Journal of the Hattori Botanical Laboratory 42: 425–465.

Steere, W. C. 1978. The mosses of Arctic Alaska. J. Cramer, Vaduz, Germany.

Steere, W. C., and **G. W. Scotter.** 1986. Bryophytes of the Cape Parry and Bathurst Inlet region, Northwest Territories. Canadian Field-Naturalist 100: 496–501.

Stotler, R., and **B. Crandall-Stotler.** 1977. A checklist of the liverworts and hornworts of North America. The Bryologist 80: 405–428.

Received 2 July 1991
Accepted 9 March 1992

Lichens of the Cape Parry and Melville Hills Regions, Northwest Territories

JOHN W. THOMSON[1] AND GEORGE W. SCOTTER[2,3]

[1]Department of Botany, University of Wisconsin, Madison, Wisconsin 53706-1381
[2]Canadian Wildlife Service, 4999 - 98 Avenue, Edmonton, Alberta, T6B 2X3
[3]Present address: R.R. 4, 59-C15, Kelowna, British Columbia V1Y 7R3

Thomson, John W., and George W. Scotter. 1992. Lichens of the Cape Parry and Melville Hills Regions, Northwest Territories. Canadian Field-Naturalist 106(1): 105–111.

Two hundred and thirty-six species of lichens and two lichen fungus parasites are reported from the Cape Parry and Melville Hills regions, Northwest Territories, Canada. New to North America are *Lecania disceptans*, and *Verrucaria ossiseda*; new to Canada are *Lecidea subduplex*, *Psorinia conglomerata* and *Rinodina lyngei*. Major range extensions are reported for *Aspicilia supertegens, Bacidia siberiensis, Ionaspis annularis, Lecanora pulicaris, Lecidea conferenda, L. phaeopelidna, L. sublimosa, Phaeophyscia decolor* and *Stereocaulon botryosum.*

Key Words: Lichens, Cape Parry, Melville Hills, Northwest Territories.

The Cape Parry and Melville Hills regions, located in the central northern edge of the continental arctic portion of North America (Figure 1), are important in providing information on the distribution of the American arctic lichens, such as whether or not the ranges extend that far from the eastern Arctic or represent easterly ranges of the Beringian (western arctic) elements in the flora. The comparative inaccessibility of these regions has left their lichen flora largely unstudied until now. The nearest lichen studies are those to the west at the Reindeer Preserve (Ahti et al. 1973), and to the east at Coppermine (Thomson 1970). G.W.S. had the opportunity to collect lichens as part of a natural resource inventory from the Cape Parry region during 1978 and from the Melville Hills region during 1990.

Description of Areas

Cape Parry lies within the northern Interior Plains Province, except for the northeastern corner which is within the Arctic Coastal Plains Province (Bostock 1970). The physiography was described in detail by Mackay (1958a, 1958b, 1963), covering all aspects of physical geography. The physiographic regions were later summarized and renamed by Yorath et al. (1969) to conform with geographic rather than geomorphic terminology.

The Melville Hills rise gradually to a maximum height of 876 m ASL. The hills are drained by the Hornaday River and Brock River towards the west, eroding deep canyons near the coast. Bluenose Lake, a large (400 km^2) lake on the eastern flank of Melville Hills, is drained northward by the Crocker River. The hills are largely composed of nearly horizontally bedded Precambrian sandstone, with local basaltic intrusive rocks. Poorly consolidated sedimentary rocks of Cretaceous age occur on the lowlands west of Melville Hills.

The Melville Hills were not glaciated during the latest Wisconsin glaciation (Dyke and Prest 1987). Ice flow pattern suggests that the late-Wisconsin glacier ice, advancing from the southeast, was deflected around Melville Hills (Craig 1960). Wood, identified as *Pinus strobus* type (R. Mott, personal communication), was found on the shores of a large lake at the headwaters of the largest tributary of the Hornaday River. This wood was dated as >41 000 years by the Geological Survey of Canada (GSC-5115). The central portion of Melville Hills has no glacial erratics, suggesting that perhaps a small portion of the uplands may have totally escaped glaciation. Although the understanding of glacial time sequence of this area requires more studies, it seems that the Melville Hills were free of ice for a much longer period of time than the rest of the neighboring Arctic mainland.

The Cape Parry region contains elements of polar semi-desert, arctic tundra, tundra-forest transition, and subarctic woodlands. The region lies between the floristically different regions of the upper Mackenzie Valley, where many Beringian species occur, and the central mainland arctic region.

The Melville Hills region is wholly within the arctic tundra region. The vegetation is influenced by local elevation and exposure. In the well-protected valleys of the lower Hornaday and Brock rivers tall willow shrubs and continuous tundra vegetation grows. At higher elevations the vegetation cover is discontinuous, with low, ground-hugging shrubs, forbs and sedges. The wet sites are dominated by sedges and cottongrass, as well as mosses. In the exposed bedrock and rock rubble areas crustose and umbilicate lichens dominate, with only scattered

dwarf shrubs and mosses. More complete descriptions of the vegetation are in the other papers of the series on this region (Cody et al. 1992; Scotter and Vitt 1992).

The climate of both regions is characterized by long cold winters, short cool summers, and relatively low precipitation. At Clinton Point on the Amundsen Gulf coast, for example, the mean annual temperature is 11.2°C, and the mean July temperature is 7.4°C (Environment Canada 1982), but frost can occur even during the summer months. The mean cumulative annual degree days above 5° is 203. The mean annual precipitation is 181.5 mm, of which 85.0 cm occurs as snow.

List of Localitites

The numbers in the list of species refer to the following localities. The approximate location of each site is given as well as the approximate elevation in metres (m).

Cape Parry (CP)

1. Polar semi-desert communities, and seepage areas near Cape Parry, 70° 10'N, 124° 40'W, 0–75 m.
3. *Salix-Carex* tundra near Paulatuk, 69° 21'N, 124° 07'W, 0-10 m.
4. *Salix* grass, *Carex*-moss, and dwarf heath communities near pingo, 69° 20'N, 124° 55'W, 15-35 m.
5. *Dryas-Carex* community near the Hornaday River, 65° 05'N, 123° 07'W, 250 m.
6. Plant communities near La Ronciere Falls, Hornaday River, 69° 05'N, 122° 51'W, 215-275 m.
7. *Dryas-Carex* and *Picea glauca*-lichen communities, 68° 27'N, 124° 06'W, 275 m.
8. Lichen-heath and white spruce-lichen, 67° 38'N, 123° 27'W, 355 m.
9. White spruce-lichen and *Dryas* communities, 67° 29'N 122° 37'W, 410 m.
11. *Picea glauca-Ledum* and limestone cliff communities, near the Horton River, 68° 49'N, 124° 25'W, 105-200 m.
12. White spruce-lichen community near the Anderson River, 68° 06'N, 125° 24'W, 230 m.
13. Deflated sand plain with white spruce, black spruce-lichen and *Carex* communities, 68° 28'N, 126° 07'W, 170 m.
14. *Dryas* tundra polygonal community, 69° 20'N, 125° 54'W, 275 m.
15. *Dryas-Carex* and *Carex* communities on undulating till and low-center polygons, 69° 41'N, 125° 08'W, 12 m.
18. Lichen, *Carex*, and white spruce-lichen communities on a peat plateau and lacustrine plain, 68° 49'N 128° 17'W, 230 m.
23. *Dryas-Carex* community on dissected till uplands, 70° 08'N, 127° 29'W, 0-35 m.

Melville Hills (MH)

2. "Hornaday Lake", 68° 42'N, 120° 48'W, 513 m.
4. 68° 36'N, 120° 24'W, 580 m.
5. 68° 26'N, 119° 50'W, 560 m.
7. Hornaday River, 68° 33'N, 120° 46'W, 490 m.
8. 68° 44'N, 121° 03'W, 660 m.
10. Hornaday River, 68° 36'N, 120° 41'W, 510 m.
11. 68° 09'N, 120° 32'W, 570 m.
13. Croker River Canyon, 69° 06'N, 119° 30'W, 340 m.
15. "Conglomerate Hill", 69° 21'N, 119° 57'W, 30 m.
17. 69° 18'N, 119° 56'W, 180 m.
19. 68° 27'N, 121° 10'W, 550 m.
22. 69° 48'N, 121° 53'W, 2 m.
23. Lower Brock Lagoon, 69° 31'N, 123° 13'W, 2 m.
24. 69° 08'N, 121° 50'W, 700 m.
29. Confluence of Hornaday River and a river from an unnamed lake, 68° 20'N, 121° 57'W, 380 m.
30. La Ronciere Falls, 69° 08'N, 122° 52'W, 215–275 m.
31. Pearce Point, 69° 45'N, 122° 38'W, 2 m.
32. Hornaday Delta, 69° 22'N, 123° 56'W, 5 m.
34. 68° 35'N, 120° 05'W, 620 m.
37. 68° 33'N, 121° 05'W, 520 m.
39. 69° 11'N, 121° 49'W, 800 m.
40. Brock Canyon, 69° 21'N, 122° 48'W, 300 m.
41. Lower Brock River, 69° 21'N, 123° 04'W, 60 m.

All specimens are filed at the herbarium of the University of Wisconsin (WIS). Nomenclature mainly follows Egan (1987, 1989, 1990) except in the Umbilicariaceae (Llano 1950) and *Usnea.*

List of Species

Acarospora veronensis Massal. MH-8.
Adelolechia pilati (Hepp) Hertel & Hafellner MH-2.
Agyrophora lyngei (Schol.) Llano MH-7.
Alectoria nigricans (Ach.) Nyl. CP-1; CP-15.
Alectoria ochroleuca (Hoffm.) Massal. CP-3; MH-10; MH-30.
Anaptychia setifera Räsänen CP-1.
Arctoparmelia separata (Th. Fr.) Hale MH-11.
Aspicilia alboradiata (Magnusson) Oxner MH-2.
Aspicilia caesiocinerea (Nyl. *ex* Malbr.) Arnold MH-34.
Aspicilia candida (Anzi) Hue MH-5; MH-39.
Aspicilia disserpens (Zahlbr.) Räsänen *in* Huusk MH-8; MH-15; CP-1; CP-3.
Aspicilia elevata (Lynge) Thomson MH-2.
Aspicilia lesleyana (Darb.) Thomson MH-2; CP1.
Aspicilia myrinii (Fr. in Myrin) B. Stein CP-1.
Aspicilia perradiata (Nyl.) Hue MH-5.
Aspicilia plicigera (Zahbr.) Räsänen MH-10.
Aspicilia ryrkaipiae (Magnusson) Oxner MH-8.
Aspicilia supertegens Arnold MH-15; CP-1. These records fill a gap between Ellesmere Island and Alaska.

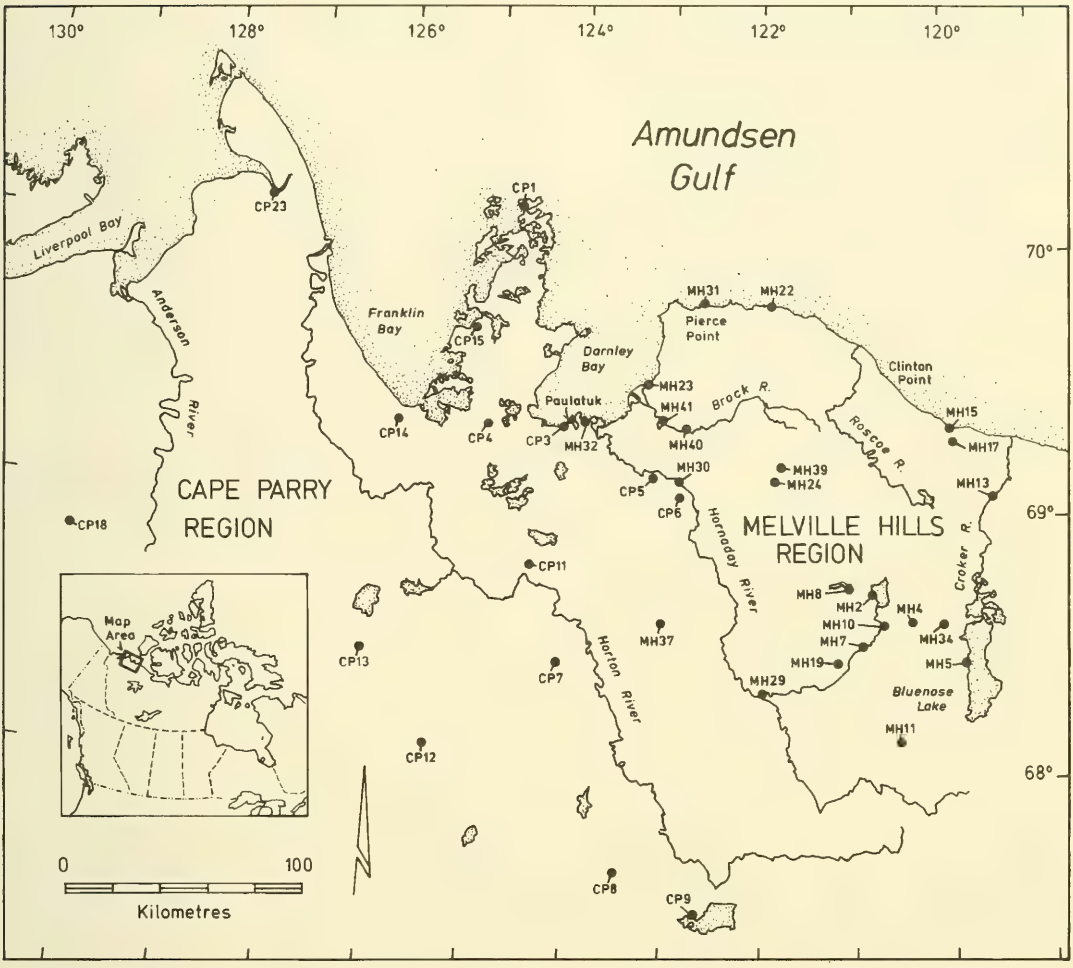


FIGURE 1. Locations of survey sites in the Cape Parry (CP) and Melville Hills (MH) regions, Northwest Territories.

Arctoparmelia separata (Th. Fr.) Hale MH-11.
Bacidia bagliettoana (Mass. & DeNot. *in* Mass.) Jatta MH-2; CP-1.
Bacidia siberiensis (Willey) Zahlbr. MH-32. This specimen on bark extends the range of this amphi-Beringian species eastwards from Lawrence Island in the Bering Sea.
Bacidia sphaeroides (Dickson) Zahlbr. CP-8.
Bryocaulon divergens (Ach.) Kärnef. MH-10; CP-3; CP-9; CP-20.
Bryoria lanestris (Ach.) Brodo & D. Hawksw. CP-9.
Bryoria nitidula (Th. Fr.) Brodo & D. Hawksw. MH-5; CP-9.
Bryoria simplicior (Vainio) Brodo & D. Hawksw. CP-8; CP-12; CP-13.
Buellia notabilis Lynge MH-2.
Buellia papillata (Sommerf.) Tuck. MH-7; MH-22; CP-1.
Buellia punctata (Hoffm.) Massal. MH-23.
Caloplaca ammiospila (Ach.) H. Olivier CP-9; CP-11.
Caloplaca borealis (Vainio) Poelt CP-4.
Caloplaca cinnamomea (Th. Fr.) H. Olivier MH-22.
Caloplaca crenularia (With.) Laundon CP-22 on bone.
Caloplaca discoidalis (Vainio) Lynge CP-1.
Caloplaca fraudans (Th. Fr.) H. Olivier MH-2; MH-8; MH-10.
Caloplaca holocarpa (Hoffm.) Wade MH-23; MH-32; CP-4.
Caloplaca jungermanniae (Vahl) Th. Fr. MH-23.
Caloplaca tiroliensis Zahlbr. MH-15.
Caloplaca tominii Savicz MH-17.
Candelariella aurella (Hoffm.) Zahlbr. MH-2; MH-5; MH-22; MH-23; CP-1 on old wood and bones.
Candelariella dispersa (Räsänen) Hakul. MH-39. Over a *Placynthium*.

Candelariella terrigena Räsänen CP-11.
Catapyrenium lachneum (Ach.) R. Sant. CP-1.
Cetraria cucullata (Bellardi) Ach. MH-10; MH-30; CP-1; CP-7; CP-9.
Cetraria delisei (Bory *ex* Schaerer) Nyl. CP-1.
Cetraria ericetorum Opiz MH-7.
Cetraria fastigiata (Del. *ex* Nyl. *in* Norrl.) Kärnef. CP-23.
Cetraria islandica (L.) Ach. MH-15; CP-6; CP9.
Cetraria nigricascens (Nyl.) *in* Kihlman) Elenkin MH-5.
Cetraria nivalis (L.) Ach. MH-7; CP-1; CP-13.
Cetraria tilesii Ach. MH-5; MH-7; MH-10; MH-11; CP-11.
Cladina mitis (Sandst.) Hustich MH-30.
Cladina stellaris (Opiz) Brodo MH-30.
Cladonia amaurocraea (Flörke) Schaerer MH-40.
Cladonia carneola (Fr.) Fr. CP-1.
Cladonia coccifera (L.) Willd. MH-10; MH-24; MH-30; CP-8.
Cladonia deformis (L.) Hoffm. MH-11.
Cladonia gracilis (L.) Willd. ssp. *gracilis* MH-11.
Cladonia pleurota (Flörke) Schaerer MH-11.
Cladonia pocillum (Ach.) O. Rich. MH-5; MH-10; MH-41; CP-11; CP-21.
Cladonia pseudorangiformis Asah. MH-22. This is a northern record for this species.
Cladonia subulata (L.) Weber *ex* Wigg. CP-8.
Cladonia sulphurina (Michaux) Fr. CP-8.
Coelocaulon muricatum (Ach.) Laundon CP-13.
Collema fuscovirens (With.) Laundon MH-7.
Collema glebulentum (Nyl. *ex* Crombie) Degel. MH-10.
Collema limosum (Ach.) Ach. MH-15. A rare species seldom collected in the American arctic, the nearest station is at Anderson River to the west.
Collema tenax (Swartz) Ach. MH-2; CP-1.
Collema undulatum Laurer *ex* Flotow var. *granulo sum* Degel. MH-2; MH-17; MH-40.
Coniosporium lecanorae Jaap CP-1. A lichenicolous fungus on *Lecanora saligna* on old wood.
Cyphelium inquinans (Smith *in* Smith & Sowerby) Trevisan CP-7. On old wood.
Dactylina arctica (Richardson) Nyl. MH-7; MH-11; CP-3.
Dactylina madreporiformis (Ach.) Tuck. MH-31.
Dactylina ramulosa (Hook.) Tuck. MH-4; MH-7; MH-20; MH-37.
Dermatocarpon miniatum (L.) Mann. MH-10; CP-11.
Dimelaena oreina (Ach.) Norman MH-2; MH-15; MH-29; CP-1.
Diploschistes muscorum (Scop.) R. Sant. CP-11.
Ephebe lanata (L.) Vainio CP-l.
Evernia divaricata (L.) Ach. MH-10.
Evernia mesomorpha Nyl. CP-7.
Evernia perfragilis Llano MH-4; MH-5; MH-7; MH-10; MH-15; CP-1.
Farnoldia jurana (Schaerer) Hertel CP-11.
Fistulariella almquistii (Vainio) Bowler & Rundel CP-3.
Fulgensia bracteata (Hoffm.) Räsänen MH-22; CP-1.
Hypogymnia austerodes (Nyl.) Räsänen CP-7.
Hypogymnia bitteri (Lynge) Ahti CP-7; CP-8; CP-9.
Hypogymnia subobscura (Vainio) Poelt MH-15; CP-1; CP-7; CP-8.
Hypogymnia vittata (Ach.) Parr CP-7.
Icmadophila ericetorum (L.) Zahlbr. CP-13.
Ionaspis annularis Magnusson CP-1. A rare species previously known from Novaya Zemlya, Sweden, Greenland, and Devon and Baffin Islands in the Canadian Arctic.
Ionaspis melanocarpa (Krempelh.) Arnold MH-10.
Kiliasia athallina (Hepp) Hafellner MH-5. The thallus over which this specimen is growing appears to be *Aspicilia* and so this specimen could represent *Kiliasia episema* (Nyl.) Hafellner which differs only in its parasitism.
Lecania arctica Lynge MH-2.
Lecania disceptans (Nyl.) Lynge CP-1; CP-11. This species is new to North America. It was described from the Chukotsk Peninsula, Konyam Bay region of Siberia based on collections of the Vega Expedition of 1878-1879 (Nylander, Flora 1884: 212). It has very large 2-celled spores, 15-25 x 7-8 μm according to Nylander (19-22 x 8-12.5 μm, in these specimens) with a very thick, 6 μm, gelatinous epispore.
Lecania fuscella (Schaerer) Körber MH-7.
Lecanora atrosulphurea (Wahlenb.) Ach. MH-2; CP-1.
Lecanora behringii Nyl. MH-23 on bone; CP-1 on old wood, CP-1 on bone.
Lecanora cenisia Ach. CP-1 on old wood.
Lecanora circumborealis Brodo & Vitik. CP-4, CP-7 on twigs.
Lecanora crenulata Hook. MH-10; CP-1 on bone.
Lecanora epibryon (Ach.) Ach. MH-2; MH-5; MH-7; MH-10; MH-11; MH-15; CP-1 numerous collections, CP-11; CP-23.
Lecanora hagenii (Ach.) Ach. MH-10.
Lecanora marginata (Schaerer) Hertel & Rambold MH-2; MH-8; MH-10; MH-15; MH-22; MH-34; CP-1 very abundant collections, duplicates will be distributed.
Lecanora nordenskioeldii Vainio MH-8; CP-1.
Lecanora polytropa (Hoffm.) Rabenh. MH-10; MH-22 on old leather strap; MH-31; MH-34.
Lecanora pulicaris (Pers.) Ach. CP-4 on *Salix*. A far north record for this species.
Lecanora rupicola (L.) Zahlbr. MH-15; MH-39; CP-1.
Lecanora saligna (Schrader) Zahlbr. MH-10; MH-22; MH-29; MH-32; CP-1.
Lecanora zosterae (Ach.) Nyl. MH-2; MH-23; CP-l (with *Pertusaria coriacea*).

Lecidea atrobrunnea (Ramond *ex* Lam. & DC.) Schaer. MH-5; CP-1.
Lecidea botryosa (Fr.) Th. Fr. CP-1.
Lecidea conferenda Nyl. CP-1. This is a westward range extension from Greenland and Newfoundland.
Lecidea hypnorum Libert. CP-8.
Lecidea lactea Flörke *ex* Schaerer MH-5; CP-1.
Lecidea lapicida (Ach.) Ach. MH-2; MH-5; MH-8; MH-22; CP-1.
Lecidea lithophila (Ach.) Ach. MH-29; MH-39; CP-1.
Lecidea lulensis (Hellbom) Stizenb. MH-24.
Lecidea paupercula Th. Fr. MH-39; CP-1.
Lecidea phaeopelidna Vainio CP-4 on Salix bark. The only previous collection in the American arctic was at the Reindeer Preserve.
Lecidea plana (Lahm. in Körber) Nyl. MH-39.
Lecidea ramulosa Th. Fr. MH-22; MH-40; CP-1 numerous collections on the seepages; CP-6; CP-11.
Lecidea subduplex (Nyl.) Nyl. CP-1. Previously reported from Europe, Greenland and Alaska. This species needs to be added to the Egan checklists.
Lecidea sublimosa Nyl. CP-1, on bone. A rare species known from Ellesmere Island, usually on humus.
Lecidea tessellata Flörke MH-15; MH-22; MH-34.
Lecidea theodori Lynge MH-39.
Lecidea turgidula Fr. CP-7 on old wood.
Lecidea umbonata (Hepp) Mudd MH-8; MH-39; CP-1.
Lecidella euphorea (Flörke) Hertel MH-23.
Lecidella spitzbergensis (Lynge) Hertel & Leuck. MH-2.
Lecidella stigmatea (Ach.) Hertel & Leuck. MH-5; MH-10; MH-15; MH-22; CP-1.
Leciographa muscigenae (Anzi) Rehm. MH-7; MH-10, parasitic on *Physconia muscigena*.
Lopadium pezizoideum (Ach.) Körber MH-11.
Masonhalea richardsonii (Hook.) Kärnef. CP-8; CP-9.
Megaspora verrucosa (Ach.) Hafellner & Wirth MH-10; MH-23; CP-6.
Melanelia incolorata (Parr) Essl. MH-15; CP-1.
Melanelia septentrionalis (Lynge) Essl. MH-11; CP-3; CP-4; CP-7.
Melanelia stygia (L.) Essl. MH-11.
Micarea assimilata (Nyl.) Coppins CP-1, 10 collections; CP-23.
Micarea denigrata (Fr.) Hedl. MH-10 on twigs.
Micarea melaena (Nyl.) Hedl. CP-1.
Nephroma arcticum (L.) Torss. MH-37.
Nephroma expallidum (Nyl.) Nyl. CP-7; CP-23.
Ochrolechia frigida (Swartz) Lynge MH-4; MH-37; CP-1; CP-9; CP-15; CP-23 (f. *thelephoroides* (Th. Fr.) Lynge.
Ochrolechia inaequatula (Nyl.) Zahlbr. CP-1.
Ochrolechia upsaliensis (L.) Massal. MH-7; MH-11; MH-40; CP-5; CP-15.
Orphniospora lapponica (Räsänen) Hafellner & R.W. Rogers MH-11.
Orphniospora moriopsis (Massal.) D. Hawksw. MH-24.
Parmelia omphalodes (L.) Ach. MH-5; MH-11.
Parmelia sulcata Taylor MH-5; CP-7.
Parmeliella tryptophylla (Ach.) Müll. Arg. MH-10; CP-1.
Parmeliopsis ambigua (Wulfen *in* Jacq.) Nyl. CP-7; CP-8.
Peltigera aphthosa (L.) Willd. MH-5; MH-10; MH-11; MH-24; CP-21; CP-23.
Peltigera canina (L.) Willd. MH-41.
Peltigera didactyla (With.) Laundon CP-3; MH-4.
Peltigera lepidophora (Nyl. *ex* Vainio) Bitter MH-40.
Peltigera malacea (Ach.) Funck. MH-40.
Peltigera neckeri Hepp *ex* Müll. Arg. MH-41.
Peltigera polydactyla (Necker) Hoffm. MH-10; MH-15; MH-19.
Peltigera ponojensis Gyel. CP-4.
Peltigera rufescens (Weis.) Humb. MH-2; MH-4; MH-7; MH-10; MH-11; MH-15; MH-23; MH-24; MH-30; MH-37; MH-40.
Peltigera scabrosa Th. Fr. MH-15; CP-1.
Pertusaria bryontha (Ach.) Nyl. MH-4 sterile but probably this.
Pertusaria coriacea (Th. Fr.) Th. Fr. CP-1 (with *Lecanora zosterae*).
Pertusaria dactylina (Ach.) Nyl. MH-15; CP-14.
Pertusaria panyrga (Ach.) Massal. MH-10; MH-17; CP-7; CP-23.
Phaeophyscia endococcinea (Körber) Moberg CP-1 on wood.
Phaeophyscia kairamoi (Vainio) Moberg CP-1. This circumboreal species is known from Alberta, British Columbia and Greenland.
Phaeophyscia sciastra (Ach.) Moberg MH-5; MH-10; MH-15; CP-1.
Physcia adscendens (Fr.) H. Olivier CP-22.
Physcia aipolia (Ehrh. *ex* Humb.) Fürnr. CP-4; CP-6.
Physcia caesia (Hoffm.) Fürnr. MH-2; MH-5; MH-7; MH-10; CP-1. One on bone.
Physcia dubia (Hoffm.) Lettau CP-1.
Physconia detersa (Nyl.) Poelt CP-1.
Physconia muscigena (Ach.) Poelt MH-4; MH-5; MH-7; MH-10; MH-15; MH-17; MH-21; MH-22; MH-30; MH-37; CP-1; CP-11.
Polyblastia cupularis Massal. MH-2 with *Rhizocarpon chioneum*; CP-1.
Polyblastia gelatinosa (Ach.) Th. Fr. MH-15; CP-1.
Polychidium muscicola (Swartz) S. F. Gray MH-30; CP-11.
Polysporina urceolata (Anzi) Brodo MH-5. This collection is a range extension for this arctic alpine species which was known from British

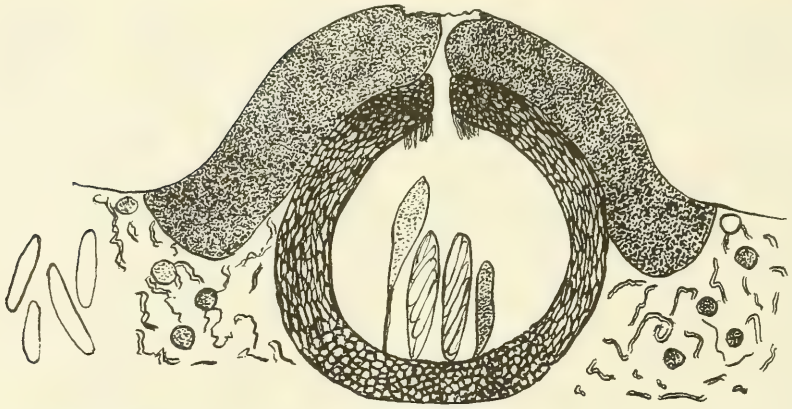


FIGURE 2. Diagram of cross section of perithecium of *Verrucaria ossiseda*. At the left are four spores 5-7 μm long.

Columbia and Bathurst Island in the Northwest Territories.

Porpidia flavocaerulescens (Hornem) Hertel & Schwab MH-39.

Porpidia macrocarpa (DC *in* Lam. & DC) Hertel & Schwab MH-5.

Porpidia thomsonii Gowan CP-1.

Protoblastenia rupestris (Scop.) Steiner MH-39.

Protoparmelia badia (Hoffm.) Hafellner MH-8; MH-39.

Pseudephebe minuscula (Nyl. *ex* Arnold) Brodo & D. Hawksw. MH-24.

Psora decipiens (Hedwig) Hoffm. MH-2; MH-7; MH-10; CP-6; CP-11.

Psora himalayana (Church. Bab.) Timdal MH-10; MH-13; MH-40.

Psora rubiformis (Ach.) Hook. *in* Smith CP-6.

Psorinia conglomerata (Ach.) G. Schneider CP-6; CP-11. New to the Canadian Arctic but previously known from Greenland and Arizona (Thomson and Nash 1976) as well as Europe.

Pyrenopsidium granuliforme (Nyl.) Forss. MH-2.

Rhizocarpon alpicola (Anzi) Rabenh. MH-5.

Rhizocarpon chioneum (Norman) Th. Fr. MH-2 (with *Polyblastia cupularis*); MH-10; CP-1.

Rhizocarpon ferax Magnusson CP-1.

Rhizocarpon geminatum Körber MH-2; MH-5; MH-8; MH-10; MH-15; MH-22; MH-31; CP-1; CP-3.

Rhizocarpon geographicum (L.) DC. MH-5; MH-8; MH-10; MH-22; MH-24; MH-34; MH-39; CP-1.

Rhizocarpon hochstetteri (Körber) Vainio MH-31.

Rhizocarpon superficiale (Schaerer) Vainio MH-15.

Rhizoplaca chrysoleuca (Smith) Zopf MH-7; MH-19.

Rhizoplaca melanopthalma (Ram. *in* Lam. & DC.) Leuck. & Poelt MH-5.

Rinodina archaea (Ach.) Arnold MH-32.

Rinodina bischoffii (Hepp) Massal. MH-2.

Rinodina lyngei Sheard ined. CP-1. Possibly new to Canada.

Rinodina roscida (Sommerf.) Arnold MH-5; MH-7; CP-1; CP-11.

Rinodina turfacea (Wahlenb.) Körber MH-11; MH-31.

Schaereria tenebrosa (Flotow) Hertel & Poelt CP-1.

Solorina bispora Nyl. MH-15; CP-6.

Solorina saccata (L.) Ach. MH-10; MH-30; CP-15.

Sphaerophorus fragilis (L.) Pers. CP-5.

Sphaerophorus globosus (Huds.) Vainio CP-15.

Sporastatia polyspora (Nyl.) Grumm. CP-1.

Sporastatia testudinea (Ach.) Massal. MH-2; MH-8; MH-15; MH-22; MH-31; CP-1.

Staurothele drummondii (Tuck.) Tuck. MH-2; MH-5, MH-8; MH-10; MH-34; CP-1.

Stereocaulon arcticum Lynge. CP-23.

Stereocaulon botryosum Ach. em. Frey CP-9. This fills an important gap between Alaska and Chesterfield Inlet.

Stereocaulon paschale (L.) Hoffm. CP-13.

Teloschistes arcticus Zahlbr. CP-1.

Thamnolia subuliformis (Ehrh.) Culb. MH-10; MH-15; MH-17; MH-40.

Thamnolia vermicularis (Swartz) Ach. *ex* Schaer. MH-5; MH-7; CP-1; CP-6; CP-15.

Thrombium epigaeum (Pers.) Wallr. MH-10.

Toninia caeruleonigricans (Lightf.) Th. Fr. CP-1.

Toninia lobulata (Sommerf.) Lynge MH-10.

Tremolecia atrata (Ach.) Hertel MH-2; MH-22; CP-1.

Tuckermannopsis pinastri (Scop.) Hale CP-7.

Umbilicaria arctica (Ach.) Nyl. MH-39.

Umbilicaria havasii Llano CP-1.

Umbilicaria hyperborea (Ach.) Hoffm. MH-11; MH-39; MH-40; CP-1.

Umbilicaria proboscidea (L.) Schrader CP-1.

Umbilicaria torrefacta (Lightf.) Schrader MH-40.

Umbilicaria virginis Schaerer MH-15; MH-19.

Usnea compacta (Räsänen) Mot. (= *U. glabrescens* (Nyl. *ex* Vainio) Vainio) CP-9.
Usnea substerilis Mot. (= *U. lapponica* Vainio acc. Egan 1987) CP-7; CP-8; CP-9.
Verrucaria arctica Lynge MH-2; MH-39.
Verrucaria cataleptoides (Nyl.) Nyl. MH-15; MH-22.
Verrucaria deversa Vainio MH-2; MH-22.
Verrucaria muralis Ach. MH-2.
Verrucaria ossiseda Lynge CP-1 on bone. This species was previously known only from Novaya Zemlya. It is new to North America. It is distinc tive in its tininess, the upper part of the involu crellum partly projecting at the bone surface to form a fleck 0.005 mm broad. The involucrellum is spreading (Figure 2) and the tiny spores, small for the genus, are 5–7 × 1.5–2 μm and elongate ellipsoid.
Xanthoria candelaria (L.) Th. Fr. CP-7; CP-l8.
Xanthoria elegans (Link.) Th. Fr. MH-2; MH-4; MH-5; MH-10; MH-15; MH-17; MH-34; CP-1 on rocks and wood, also var. *splendens* (Darbish.) Christ. *ex* Poelt on bones.
Xanthoria sorediata (Vainio) Poelt CP-1 on wood.

Acknowledgments

G. W. S. wishes to acknowledge the support of Canadian Parks Service and the Canadian Wildlife Service.

Literature Cited

Ahti, T., G. W. Scotter, and **H. Vänskä.** 1973. Lichens of the Reindeer Preserve, Northwest Territories, Canada. The Bryologist 76: 48–76.

Bostock, H. S. 1970. Physiographic subdivisions of Canada. Pages ll–30 *in* Geology and economic minerals of Canada. *Edited by* R.J.W. Douglas. Geological Survey of Canada, Economic Geology Report No. 1, fifth edition.

Cody, W. J., G.W. Scotter, and **S. C. Zoltai**. 1992. Vascular plant flora of the Melville Hills Region, Northwest Territories. Canadian Field-Naturalist 106 (1): 87–99.

Craig, B. G. 1960. Surficial geology of north-central District of Mackenzie, Northwest Territories. Geological Survey of Canada. Paper 60-18.

Dyke, A. S., and **V. K. Prest.** 1987. Late Wisconsin and Holocene retreat of the Laurentide Ice Sheet. Geological Survey of Canada, Map 1702A.

Egan, R. S. 1987. A fifth checklist of the lichen-forming, lichenicolous and allied fungi of the Continental United States and Canada. The Bryologist 90: 77–173.

Egan, R. S. 1989. Changes to the "Fifth checklist of the lichen-forming, lichenicolous and allied fungi of the Continental United States and Canada" Edition I. The Bryologist 92: 68–72.

Egan, R. S. 1990. Changes to the "Fifth checklist of the lichen-forming, lichenicolous and allied fungi of the Continental United States and Canada" Edition II. The Bryologist 93: 211–219.

Environment Canada. 1982. Canadian climate normals. Volume 2. Temperature; Volume 3. Precipitation; Volume 4. Degree Days. Atmospheric Environment Service, Downsview, Ontario.

Llano, G. A. 1950. A monograph of the lichen family Umbilicariaceae in the western hemisphere. Navexos P-831: 1–281. Office of Naval Research, Washington, D. C.

Mackay, J. R. 1958a. The Anderson River map area, N. W. T. Department of Mines and Technical Survey, Geographical Branch Memoir No. 5. 137 pages.

Mackay, J. R. 1958b. The valley of the lower Anderson River. N. W. T., Department of Mines and Technical Survey, Geographical Bulletin 11: 36–56.

Mackay, J. R. 1963. The Mackenzie Delta area, N.W.T. Department of Mines and Technical Survey, Geographical Branch Memoir No. 8. 202 pages.

Scotter, G. W., and **D. H. Vitt.** 1992. Bryophytes of the Melville Hills Region, Northwest Territories. Canadian Field-Naturalist 106(1): 100–104.

Thomson, J. W. 1970. Lichens from the vicinity of Coppermine, Northwest Territories. Canadian Field-Naturalist 84: 155-164.

Thomson, J. W. and **T. H. Nash, III.** 1976. Three new lichens from the Southwest: *Xanthoria concinna* sp. nov., *Lecanora collatolica* sp. nov., and *Toninia conglomerata.* The Bryologist 79: 350–353.

Yorath, C. J., H. R. Balkwill, and **R. W. Klassen.** 1969. Geology of the eastern part of the Northern Interior and Arctic Coastal Plains, Northwest Territories. Geological Survey of Canada Paper 68–27. 29 pages.

Received 24 June 1991
Accepted 28 February 1992

Use of Roadside Salt Licks by Moose, *Alces alces*, in Northern New Hampshire

Brian K. Miller and John A. Litvaitis

Wildlife Program, Department of Natural Resources, University of New Hampshire, Durham, New Hampshire 03824

Miller, Brian K., and John A. Litvaitis. 1992. Use of roadside salt licks by Moose, *Alces alces*, in northern New Hampshire. Canadian Field-Naturalist 106(1):112–117.

We investigated use of roadside salt licks by 14 transmitter-equipped Moose (*Alces alces*) during June – November 1987 and June – August 1988. Roadside licks formed from runoff of road salt and contained much higher levels of sodium ($\bar{x}$ = 628.5 ppm) than roadside puddles ($\bar{x}$ = 45.9 ppm), or stream water ($\bar{x}$ = 5.2 ppm). Females visited licks more often (8% of telemetry locations) than males (2% of locations) (P = 0.049). Frequency of use varied from 6% of telemetry locations during summer (June – August) to 12% of locations during autumn (September – November) for females, and from 1 to 3% among males for the same seasons. The average distance between seasonal centers of activity and roadside licks was approximately 60% greater among males (10.1 km) than among females (6.4 km) (P = 0.011). There was no correlation between that distance and the size of seasonal home ranges. However, home ranges of 11 Moose (3 males and 8 females) were elongated and incorporated at least one lick. All home ranges converged on the area containing the roadside licks. Implications associated with roadside licks include increased Moose-vehicle collisions, and potential increased Brainworm (*Parelaphostrongylus tenius*) infections among Moose from White-Tailed Deer (*Odocoileus virginianus*) that also used licks.

Key Words: Moose, *Alces alces*, sodium, salt lick, New Hampshire.

Sodium is essential for maintaining osmotic and pH balance, blood fluid volume, muscle contractions, and nerve transmissions in vertebrates (Robbins 1983). However, sodium is scarce in many ecosystems that do not receive marine aerosols (Botkin et al. 1973). Consequently, herbivores may travel to naturally occurring mineral licks to consume mineral-enriched soil or water in an apparent effort to maintain a positive sodium balance (Weeks and Kirkpatrick 1976; Jones and Hanson 1985). For example, the hunger for sodium has resulted in extensive movements to mineral springs by Moose in Alberta (Best et al. 1977), and influenced habitat-use patterns of Moose in Quebec (Joyal and Scherrer 1978). Other researchers also have observed that Moose may travel long distances to feed on aquatic plants that are rich in sodium (Fraser et al. 1980; Crossley 1985; Leptich 1986).

In northern New Hampshire, we observed Moose using roadside salt licks that formed in low-lying areas from the runoff of road salt. We speculated that roadside licks are an important habitat component and as a result, influenced the movement patterns of Moose in this region. Therefore, the objectives of our study were to examine the frequency of visits by Moose to licks, distance traveled to licks from seasonal activity centers, and the influence of the location of licks on the configuration of seasonal home ranges of Moose.

Study Area

Our study was conducted in northern New Hampshire within the township of Pittsburg (45°10'N, 71°10'W). This region was in the ecotone between coniferous forests to the north and deciduous forests to the south (Westveld et al. 1956). The soil had developed from glacial till of granitic origin, and most of the parent material was low in basic cations (Williams et al. 1943). Broad valleys were interspersed with mountains and wetland areas, and elevations ranged from 396 to 1112 m above sea level. Most of the area was owned by a private timber company and had an extensive network of logging roads. Dominant overstory species on poorly drained sites included spruce (*Picea mariana* and *P. rubens*), Balsam Fir (*Abies balsamea*), Tamarack (*Larix laricina*) and Northern White Cedar (*Thuja occidentalis*). On high elevations, Red Spruce (*P. rubens*) and Balsam Fir were common. Mid-slope areas were dominated by Yellow and White birch (*Betula alleghaniensis, B. papyrifera*), Sugar Maple (*Acer saccharum*), aspen (*Populus tremuloides*), and Beech (*Fagus grandifolia*). The climate was temperate, with an average annual temperature of 3°C (NOAA 1987). Mean daily temperature ranged from –13°C in January, to 17°C in July (NOAA 1987). Annual precipitation in 1987 was 100 cm.

Methods

We identified 12 licks along a 25-km section of Route 3 in Pittsburg by repeatedly observing Moose at these sites. We characterized licks as one central site and a 300-m radius around it. The immediate lick area included patches of bare soil or mud, a small area of standing water, and well-worn animal

TABLE 1. Average mineral concentration (ppm) in samples of water from three roadside salt licks, three nearby streams, and three roadside puddles in Pittsburg, NH, during May 1988.

Element	Lick	Puddle	Stream
Na	628.5 (362.5–1126.1)[a]	45.9 (19.0–74.9)	5.2 (5.0–5.5)
K2.1	0.2 (1.4–3.0)	1.4 (0–0.3)	(1.1–1.6)
Ca	21.1 (9.4–37.7)	3.9 (2.0–5.2)	4.0 (3.6–4.7)
Mg	3.2 (2.6–3.6)	0.6 (0.3–1.0)	0.6 (0.6–0.7)
P	0.0	0.0	0.0

[a]Range of values.

trails that radiated from it. Most licks contained standing water through October, but several became dry during late summer and early autumn. Unfiltered water samples from three licks were collected monthly from May to October 1988. We obtained samples from a spring source, if present, to minimize contamination by animal urine and care was taken to avoid collecting suspended solid matter (Fraser et al. 1980). During May 1988, samples also were collected from three roadside puddles and three streams in the study area. Roadside puddles were small (usually < 1 m radius), ephemeral accumulations of rainwater that did not receive repeated use by Moose. Sodium, potassium, calcium, phosphorus, and magnesium content were analyzed in all samples by plasma emission spectroscopy (Suburban Experiment Station, Waltham, Massachusetts).

During August – September 1986 and 1987, Moose were located at or near roadside licks along Route 3 and immobilized with xylazine hydrochloride (2 mg/kg estimated body weight) injected by a projectile syringe fired from a capture rifle. Sedated Moose were fitted with motion-sensitive radio transmitters (Telonics Inc., Mesa, Arizona), marked with ear tags, and administered an antagonistic drug (yohimbine hydrochloride, 0.6 mg/kg estimated body weight). We classified each Moose as a yearling or adult according to body size (Peterson 1955).

Movements of transmitter-equipped Moose in relation to licks were monitored from June – November 1987 and June – August 1988. No Moose visits to the licks were recorded during winter (Miller 1989). Triangulation was our major technique of locating marked Moose. All two-bearing locations with an angle of intersection between 45 and 135° were used in the analysis. Otherwise, we used three bearings to estimate the location of a Moose. Accuracy of this method of location was evaluated using a blind test of reference transmitters placed in known locations. The average triangulation error was 215 m (SE = 27.5 m, n = 20) from the actual location of reference transmitters. Therefore, locations within 0.5 km of a lick site were considered as a lick visit. We monitored transmitter-equipped Moose throughout the day, with 90% of the locations obtained between 0800 and 2400 hrs. Each Moose was located approximately every 2.5 days. In addition, individuals were periodically monitored from 4–8 hrs. However, only locations that were separated by > 8 hrs were considered independent (Miller 1989) and included in the analysis.

Program HOMERANGE (Samuel et al. 1985) was used to estimate seasonal home ranges (minimum convex polygon technique [Odum and Kuenzler 1955] and seasonal centers of activity, harmonic mean [Dixon and Chapman 1980]). The frequency of lick use by Moose was determined on a seasonal basis (summer: 1 June – 15 September, autumn: 16 September – 30 November), and the distance from an activity center of an individual Moose to the nearest roadside lick also was determined for each season.

We compared differences in the number of visits to licks among seasons and between sexes using Kruskal-Wallis and Wilcoxon rank-sum statistics, respectively (Ott 1988). Use-availability analysis of licks was performed using the methods described by Neu et al. (1974). The proportion of the study area that contained licks was estimated by dividing the combined area within a 0.5 km radius of each lick by the study area. The study area was delineated by connecting the outermost locations of all transmitter-equipped Moose. Significance for all tests was assigned at the 0.05 probability level.

Results

During May, mean ± SE levels of sodium were higher at licks (628.5 ± 249.0 ppm) than in puddles (45.9 ± 16.2 ppm) or streams (5.2 ± 0.1 ppm) with smaller differences for potassium, calcium, and magnesium (Table 1). Although roadside puddles contained relatively high concentrations of sodium in comparison to stream samples, we observed Moose to use this source only infrequently. The average sodium concentration at licks ranged from 628.5 ppm

TABLE 2. Average mineral concentration (ppm) in water samples from roadside salt licks collected during May-October in Pittsburg, New Hamphire, 1988

	May	June	July	August	September	October
Na	628.0 (362.5–1126.1)[b]	225.8 (119.1–419.4)	91.5 (30.5–159.6)	167.6 (95.9–277.7)	136.2 (76.1–196.3)	123.0 (80.7–165.4)
K	21.1 (1.4–3.0)	12.9 (5.3–24.6)	2.3 (2.1–2.6)	5.4 (12.9–7.0)	3.5 (1.1–4.6)	3.5 (1.4–4.1)
Ca	21.1 (9.4–37.7)	28.2 (14.8–52.4)	5.6 (3.9–8.2)	15.0 (9.7–16.6)	9.7 (2.2–14.7)	5.0 (2.2–5.1)
Mg	3.2 (2.5–3.6)	5.0 (3.3–6.4)	1.0 (10.7–1.4)	3.0 (1.9–3.6)	1.5 (0.5–1.7)	1.2 (0.5–1.8)

Three licks were sampled during May through August, and two licks sampled during September and October because a stream inundated one lick.
[b]Range of values.

in May to 91.5 ppm in October (Table 2). This wide variation may have been partly a result of differences in local applications of winter road salt, topography, and rainfall.

Fourteen transmitter-equipped Moose (three males and 11 females) were located 1422 times to provide information on lick use. For all seasons combined, visits to licks comprised a greater percentage of the locations of females (7%) than among males (2%) (Wilcoxon rank-sum test, $Z = 3.86$. $P = 0.049$) and varied from 6% (summer) to 8% (autumn) among females, and from 1 to 3% among males (Figure 1). Based on the availability of lick habitat, use of licks by females was greater than expected during all seasons ($P < 0.05$). Because each Moose was located approximately each 2.5 days, some visits to licks undoubtedly were undetected. The 13 Moose that made known visits to licks used an average of 1.5 licks/animal. Three Moose (two males and one female) used at least two different licks, and one female used up to four lick sites. Trips to licks apparently were made quickly and along direct routes. For instance, female Number 220 (with calf) travelled 7.5 km from the core area of her summer range to a roadside lick in < 8 hrs.

The average distances between seasonal centers of activity and the nearest roadside lick varied between males and females (summer 1987: males = 11.0 km, n = 3; females = 5.6 km, n = 7; autumn 1987: males = 10.2 km, n = 3; females = 6.1 km, n = 10; summer 1988: males = 10.2 km, n = 3; females = 4.7 km, n = 8), but these distances were not significantly different. However, for ll seasons combined, the mean ± SE distance between activity centers and roadside licks among males (10.1 ± 1.2 km)

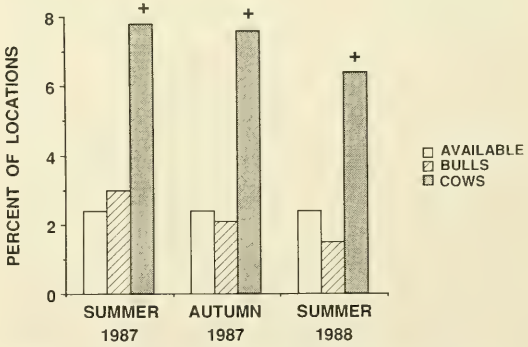


FIGURE 1. Percentage of locations of transmitter-equipped Moose at roadside salt licks and availability of lick habitat in Pittsburg, New Hamphire, 1987-1988. Number of locations among males was: summer 1987 = 110, autumn 1987 = 89, summer 1988 = 134; and among females: summer 1987 = 299, autumn 1987 = 313, and summer 1988 = 346. Use that was greater than availability is indicated (+) ($P < 0.05$).

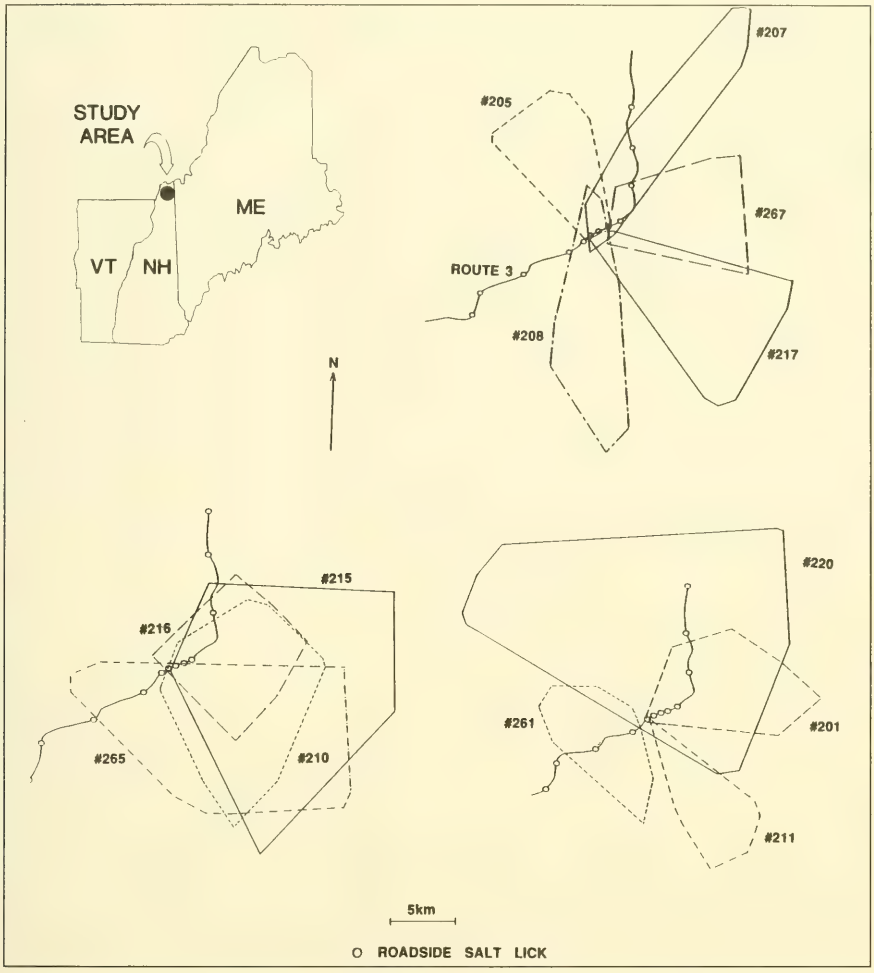


FIGURE 2. Study area location and configuration of summer-autumn home ranges of transmitter-equipped Moose in relation to roadside salt licks, Pittsburg, New Hampshire, 1987–1988. Roadside salt licks along Route 3 are identified with circles.

was approximately 60% greater than among females (6.4 ± 1.1 km) ($Z = 2.56$, $P = 0.011$).

Seasonal home ranges were estimated for 10 Moose (three males and seven females) during summer 1987, 13 Moose (three males and 10 females) during autumn 1987, and for 11 Moose (three males and eight females) during summer 1988 (Miller 1989). There was no correlation between the size of seasonal home ranges and the distance between the nearest lick and seasonal centers of activity home ranges ($\chi^2 = 0.03$, $P = 0.37$). However, all Moose, except four females (whose centers of activity were < 0.75 km to the nearest lick), had elongated home ranges during summer and/or autumn that encompassed at least one lick (Figure 2). All home ranges converged on the area that contained the licks.

Discussion

Moose in our study area used roadside licks in spite of an availability of ponds that contained aquatic plants. The average distance to a potential aquatic feeding site (any beaver flowage, lake, or slow moving river) from each telemetry location of Moose was 783 m (range = 652–960 m, Miller 1989). Although aquatic plants contain high amounts of sodium in comparison to terrestrial plants (Botkin et al. 1973; Fraser et al. 1984; Crossley 1985), the use of licks may be advantageous because licks may provide a more efficient means of obtaining sodium or other minerals than aquatic plants. Belovsky (1978) calculated that a Moose at a lick ingested sodium 15 times faster than at an aquatic feeding site. Also, aquatic plants have a lower energy content than ter-

restrial browse species (Belovsky and Jordan 1981, Fraser et al. 1984). Therefore, by obtaining sodium from mineral licks, the time and energy saved by Moose could be spent locating and feeding on more nutritious forage.

The greater frequency of visits to licks by females may reflect their greater need for sodium, resulting from calf growth, lactation, and estrus (Belovsky and Jordan 1981). Couturier and Barrette (1988) observed that lactating cows and their calves were among the most frequent users of mineral springs in the Gaspe Peninsula of Quebec. In our study, three out of four and six out of six of the females for which reproductive status could be determined during 1986 and 1987, respectively, had at least one calf.

Moose in our study often had elongated home ranges that included at least one lick. Because these individuals were captured at or near roadside licks, our sample may have been biased in favor of animals using roadside licks. However, other researchers observed a similar pattern in relation to aquatic feeding sites (Fraser et al. 1980; Crossley 1985; Leptich 1986). The apparent significance of roadside licks to Moose was most pronounced by a female (with calf) that had two core areas within her home range, 0.75 km and 19 km from a roadside lick. She periodically traveled 13–15 km from an area with aquatic vegetation to a roadside lick and spent approximately two - three weeks at this site.

Moose at licks often were indifferent toward observers. As a result, Moose watching and photography are now popular recreational activities in this region. However, Moose at licks also may be vulnerable to poachers. Additionally, both Moose and White-tailed Deer (*Odocoileus virginianus*) have been seen at the same lick. Therefore, the probability of Brainworm infections (*Parelaphostrongylus tenius*) among Moose may increase. Fraser and Thomas (1982) also demonstrated that the presence of roadside licks increased the frequency of Moose-vehicle collisions. In Ontario, property damage was estimated at $1500 per accident during 1977-1980 (E. R. Thomas, unpublished data cited in Fraser and Hristienko [1982]). As a result, roadside licks may be considered as both beneficial and detrimental to local Moose populations.

Acknowledgments

We thank K. Klein, E. Orff, and S. Williamson for their efforts in capturing and marking Moose. D. Covell, T. Hodgman, R. Hunt, and N. Miller provided valuable field assistance. D. Fraser, J. Kanter, T. Nudds, P. Pekins, M. Thompson, and H. Weeks reviewed early drafts of this report. Financial support was provided by the New Hampshire Fish and Game Department (Pittman-Robertson Project Number W-12-R) and the New Hampshire Agricultural Experiment Station. This is Scientific Contribution 1636 of the New Hampshire Agricultural Experiment Station.

Literature Cited

Belovsky, G. E. 1978. Diet optimization in a generalist herbivore: the moose. Theoretical Population Biology 14: 105–134.

Belovsky, G. E., and **P. A. Jordan.** 1981. Sodium dynamics and adaptations of a moose population. Journal of Mammalogy 62: 613–621.

Best, D. A., G. M. Lynch, and **O. J. Rongstad.** 1977. Annual spring movements of moose to mineral licks in Swan Hills, Alberta. Proceeding of the North American Moose Conference and Workshop 13: 215–228.

Botkin, D. B., P. A. Jordan, A. S. Dominski, H. S. Lowendorf, and **G. E. Hutchinson.** 1973. Sodium dynamics in a northern ecosystem. Proceedings of the National Academy of Science (USA) 70: 2745–2748.

Couturier, S., and **C. Barrette.** 1988. The behavior of moose at natural mineral springs in Quebec. Canadian Journal of Zoology 66: 522–528.

Crossley, A. 1985. Summer pond use by moose in northern Maine. M. Sc. thesis, University of Maine, Orono. 39 pages.

Dixon, K. R., and **J. A. Chapman.** 1980. Harmonic mean measure of animal activity areas. Ecology 61: 1041–1044.

Fraser, D., E. R. Chavez, and **J. E. Paloheimo.** 1984. Aquatic feeding by moose: selection of plant species and feeding areas in relation to plant chemical composition and characteristics of lakes. Canadian Journal of Zoology 62: 809–887.

Fraser, D., and **H. Hristenko.** 1982. Moose-vehicle accidents in Ontario: a repugnant solution? Wildlife Society Bulletin 10: 266–270.

Fraser, D., E. Rearden, F. Dieken, and **B. Loescher.** 1980. Sampling problems and interpretation of chemical analysis of springs used by wildlife. Journal of Wildlife Management 44: 623–631.

Fraser, D., and **E. R. Thomas.** 1982. Moose-vehicle accidents in Ontario: relation to highway salt. Wildlife Society Bulletin 10: 261–265.

Jones, R. L., and **H. C. Hanson.** 1985. Mineral licks, geophagy, and biochemistry of North American ungulates. Iowa State University Press, Ames. 301 pages.

Joyal, R., and **B. Scherrer.** 1978. Summer movements and feeding by moose in western Quebec. Canadian Field-Naturalist 92: 252–258.

Leptich, D. J. 1986. Summer habitat selection by moose in northern Maine. M.Sc. thesis, University of Maine, Orono. 42 pages.

Miller, B. K. 1989. Seasonal movement patterns and habitat use of moose in northern New Hampshire. M.Sc. thesis, University of New Hampshire, Durham. 63 pages.

NOAA (National Oceanic and Atmospheric Administration). 1987. Climatological Data Annual Summary, New England. 99: 13.

Odum, E. P., and **E. J. Kuenzler.** 1955. Measurement of territory and home range size in birds. Auk 72: 128–137.

Ott, L. 1988. An introduction to statistical analysis and data analysis. PWS-Kent Publishing Co., Boston. 835 pages.

Peterson, R. L. 1955. North American moose. University of Toronto Press, Toronto. 280 pages.

Robbins, C. T. 1983. Wildlife feeding and nutrition. Academic Press, New York. 343 pages.

Samuel, M. D., D. J. Pierce, E. O. Garton, L. J. Nelson, and **K. R. Dixon.** 1985. Users manual for program HOMERANGE. Forestry, Wildlife, and Range Experiment Station Technical Report 15. University of Idaho, Moscow. 70 pages.

Weeks, H. P., Jr., and **C. M. Kirkpatrick.** 1976. Adaptations of white-tailed deer to naturally occurring sodium deficiencies. Journal of Wildlife Management 40: 610–625.

Westveld, M. R., R. I. Asham, H. I. Baldwin, R. P. Holdsworth, R. S. Johnson, J. H. Lambert, H. J. Lutz, L. Swain, and **M. Standish.** 1956. Natural forest vegetation zones of New England. Journal of Forestry 54: 332–338.

Williams, B. H., W. H. Coates, and **P. N. Scripture.** 1943. Soil survey, Coos County, New Hampshire. U. S. Department of Agriculture Services, 1937, Number 5.

Received 17 January 1991
Accepted 10 February 1992

Use of Woody Ground Litter as a Substrate for Travel by the White-Footed Mouse, *Peromyscus leucopus*

John V. Planz[1] and Gordon L. Kirkland, Jr.[2]

[1]Section of Mammals, Carnegie Museum of Natural History, 5800 Baum Blvd., Pittsburgh, PA 15206
[2]Vertebrate Museum, Shippensburg University, Shippensburg, Pennsylvania 17257

Planz, John V., and Gordon L. Kirkland, Jr. 1992. Use of woody ground litter as a substrate for travel by the White-footed Mouse, *Peromyscus leucopus*. Canadian Field-Naturalist 106(1): 118–121.

Use of woody ground litter by white-footed mice (*Peromyscus leucopus*) as a substrate for travel was studied in a middle-aged, deciduous forest in southcentral Pennsylvania using a fluorescent pigment tracking technique. Mark-recapture data on 45 P. leucopus and mapped trails of 17 individuals were obtained from April through December 1986. Following collection of data on the movements and habitat utilization of white-footed mice in an unmanipulated system, selected quadrats within the study site were cleared of all woody ground litter greater than 10 mm in diameter to assess the importance of such litter on habitat utilization and movements by *P. leucopus*. There was a significant decrease in the number of captures of white-footed mice on cleared plots between the pre- and post-litter removal phases of the study. Although woody ground litter comprised only an estimated 8.2% of the ground cover on the study site, approximately half the total distance travelled by *P. leucopus* was on woody ground litter. The use of woody ground cover for travel by P. leucopus may represent a trade-off between the risks of predation from rattlesnakes (*Crotalus horridus*) that use ground litter as ambush sites and nocturnal raptors that are more common and employ auditory cues to locate prey.

Key Words: White-footed mouse, *Peromyscus leucopus*, fluorescent tracking, deciduous forest, habitat use, woody ground litter, predation risk.

Knowledge of how mammals exploit their environments is a key to an understanding of their ecology; however, analysis of home range use by many small mammals, including White-footed Mice (*Peromyscus leucopus*), is rendered difficult by their nocturnal habits. Data from standard mark-recapture techniques do not provide information on what individuals do when they are not in traps. However, tracking animals marked with dry fluorescent pigments (Lemen and Freeman 1985) yields detailed information on routes of travel, location of den sites, and behavior (e.g., location of grooming and feeding sites), and thus can greatly increase our knowledge of home range use by nocturnal small mammals. This relatively inexpensive technique was employed by Graves et al. (1988) to compare use of ground and arboreal microhabitats by *P. leucopus* and the Deer Mouse (*P. maniculatus*), and by Kaufman (1989) to study social interactions in *P. maniculatus*. In this study, we employed a fluorescent pigment tracking technique, in concert with experimental manipulation of woody litter (dead branches, downed trees and logs), to determine the extent to which White-footed Mice use woody ground litter as routes of travel, and thereby to assess the influence of this habitat feature on spatial use by this species.

Study Site and Methods

The study site was located in a middle-aged, deciduous forest on South Mountain in southcentral Pennsylvania, Cumberland County, 3.9 km S, 3.2 km E, Cleversburg, elevation 490 m (40° 00'N, 77° 27'W). The overstory was dominated by Chestnut Oak (*Quercus prinus*) with diameter at breast height (dbh) ranging from 10 cm to 40 cm. Other trees included Black Oak (*Q. velutina*) and Red Maple (*Acer rubrum*). Living ground cover consisted mainly of Mountain Laurel (*Kalmia latifolia*) and blueberry (*Vaccinium* sp.). Estimates of four ground cover classes were based on data from 1-m^2 samples at trap stations and consisted of open ground-leaf litter (49.6%), living ground cover, including shrubby vegetation (40.6%), woody ground cover, i.e., dead branches, logs, and stumps (8.2%), and rocks (0.8%) (Kirkland et al. 1985).

We employed a 7 by 7 station sampling grid with stations located at 15-m intervals to live trap *P. leucopus*. One large (7.5 by 9.0 by 23.0 cm) Sherman live trap baited with rolled oats was placed at each station. We opened traps in late afternoon (1600-1800 h) and checked them within two hours following sunset (2100-2300 h), at which time traps were closed to prevent marked animals from re-entering. Captured *P. leucopus* were marked by toe-clipping, sexed, measured (total, tail, and hind foot lengths), weighed, and aged (juvenile, subadult, or adult). Juveniles had grey pelage and body mass < 11 g; subadults retained traces of juvenile pelage on head and base of tails and had body mass ≥ 11 g and ≤ 17 g); and adults lacked any residual grey pelage and had a body mass > 17 g.

We followed the procedures of Lemen and Freeman (1985) for marking mice with dry fluorescent pigments (Radiant Color Co. Richmond, CA 94804). Mice were released at the trap station where captured. In an attempt to minimize our influence on the movements of marked mice, we did not follow and mark pigment trails until the next night. We used a portable UV lamp (UV Products Blak-Ray, Model ML-49) to reveal pigments deposited by marked individuals on the substrate or on other objects they touched. Pigment trails were followed from the release point until pigment could no longer be detected with the black light. We marked pigment trails with color-coded metal stake flags placed approximately every 10 cm along trails and wherever trails made a sharp turn. Sections of trails on logs or in shrubs were marked by placing flags horizontally along the elevated substrate. Trails were surveyed and mapped using a liquid-filled compass (Suunto, RA69) and fiberglass tape. Mapping involved taking azimuthal readings from the starting point and recording the direction and straight line distance of travel for each trail segment.

Because the fluorescent pigments are water-soluble, marking and tracking were carried out only during non-rainy weather. Also, because high ambient light renders fluorescing pigments less visible and trails difficult to follow, we did not mark and track mice during the seven days preceding or following a full moon. Individuals were selected for tracking with fluorescent pigments based on sex (approximately equal numbers of males and females), relative age (no juveniles), prior capture records, and proximity of captures to cleared experimental quadrats, which are described below.

Data were recorded on movements and habitat use by *P. leucopus* in an unmanipulated system for five nights between 17 April to 23 October 1986. Five quadrats, each 15 by 15 m with the trap station at the center, were then cleared of all woody litter greater than 10 mm in diameter to assess the importance of such litter to habitat use by this species. This permitted us to compare trapping success and movements of dusted animals in experimental (litter removal) and control quadrats. We selected experimental quadrats on the basis of amount of woody ground litter present and prior use by *P. leucopus* as indicated by previous captures at trap stations in these quadrats. Plots characterized by little woody litter and low use by mice were not selected for clearing. None of the five litter removal plots were contiguous. After litter removal, mice were tracked on four nights between 26 October and 3 December 1986.

Results

Forty-five *P. leucopus* were captured 102 times; 17 were marked with fluorescent pigments and subsequently tracked. Marked mice used woody ground litter extensively in their movements, with more than 50% of total trail lengths along this substrate (Table 1). Comparisons of adults and subadults in their respective use of litter, open ground, and shrubs as avenues of travel revealed no significant differences (Mann-Whitney U tests). Comparison of the use of woody litter versus open ground-leaf litter relative to the availability of the two substrates as potential routes of travel indicated that *P. leucopus* preferred travel on woody litter over travel on open ground ($\chi^2 = 733.8$, d.f. = 1, $p < 0.0001$).

Removal of woody litter from experimental quadrats resulted in a significant decrease in the frequency of captures of *P. leucopus* in those quadrats (Table 2). This decrease was not observed in quadrats that were either adjacent or not adjacent to the experimental plots (Table 2).

Based on measurements of overall trail lengths, activity of *P. leucopus* in the cleared quadrats and in plots adjacent to cleared quadrats did not change between the two phases of the study (Mann-Whitney U Test). However, the pattern of move-

TABLE 1. Comparison of travel by adult and subadult *P. leucopus* on different substrates as revealed by fluorescent tracking.

	Mean Mean (m)	Mean (%) Trail Trail Length Woody Litter	Mean (%) Trail Length (m) On Open Ground	Mean (%) Trail Length In Shrubs
Adults (n = 11)	48.15	25.51 (53.0%)	20.42 (42.4%)	2.22 (4.6%)
Subadults (n = 6)	34.34	17.35 (50.5%)	15.56 (45.3%)	1.43 (4.2%)
Combined (n = 17)	43.27	22.63 (52.3%)	18.70 (43.2%)	1.94 (4.5%)

*P < 0.05; **P < 0.005

TABLE 2. Capture of *P. leucopus* on litter removal (experimental), adjacent, and non-adjacent quadrats during pre- and post-litter removal sampling.

	Number of Captures			
	Litter Removal Quadrats (N = 5)	Adjacent Quadrats (N = 21)	Non-adjacent Quadrats (N = 23)	Chi-Square
Pre-litter Removal (5 sampling sessions)	15	26	26	11.07**
Post-litter Removal (4 sampling sessions)	3	16	16	0.17
Chi-square	4.55*	0.47	0.47	

*P < 0.05; **P < 0.005

ment differed between pre- and post-litter removal in the cleared plots. The mean length of ground trail segments in experimental plots increased from the pre-litter removal phase ($\bar{x}$ = 1.5 m) to the post-litter removal phase ($\bar{x}$ = 4.1 m; t = 6.35, d.f. = 57, p < 0.001). Following litter removal, mice evinced longer, straight-line movements across the cleared areas, in contrast to short distance movements with numerous changes in direction prior to litter removal.

Discussion

Our results are consistent with those of Graves et al. (1988), who noted the tendency of *P. leucopus* to travel along downed logs and branches, rather than directly on the ground. In their analysis of habitat use and landmarks by *P. leucopus*, Barry and Franq (1980) found that logs were an important feature influencing the microdistribution of White-footed Mice in southern New Hampshire. Logs served as navigational landmarks, and when encountered, were used by *P. leucopus* as routes of travel. The extensive use of woody ground litter by *P. leucopus* is thus similar between areas where the Deer Mouse (*P. maniculatus*), which might influence the activity and movements of *P. leucopus*, is present (Graves et al. 1988) and study sites where this species does not occur (Barry and Franq 1980; present study).

Prior to litter removal, experimental plots were characterized by large amounts of woody ground litter and extensive use by *P. leucopus*. Litter removal decreased *P. leucopus* activity in these high-use areas to levels comparable to those in other portions of the study area. As evidenced by number of captures, there was no change following litter removal in the level of activity in other quadrats (Table 2). Thus the effect of litter removal was limited to experimental plots and was not accompanied by changes, either increases or decreases, in utilization of other portions of the study area.

Peromyscus leucopus responded significantly to the removal of litter by shifting their pattern of movement while on the ground from many short-distance movements interspersed with changes in direction to a few long-distance straight-line movements. Although mice were not observed while these trails were being made, evidence left in the form of pigment trails gave the impression of a shift from relatively slow, deliberate movements to rapid, straight-line dashes across litter-free zones. One interpretation of this shift in movement pattern, coupled with decreased utilization of cleared plots, is that *P. leucopus* perceived experimental plots to be less secure microhabitats following removal of litter.

The results of this study raise the question of why *P. leucopus* travel on woody litter to such an extent. One way to view selection of woody litter as a preferred travel substrate is in the context of predator avoidance. Upon release, mice initially moving on the ground were clearly audible as they traveled across dry leaf litter. In contrast, mice initially travelling on logs and branches made less noise. It is the conventional wisdom of small mammal collectors that trapping success increases during inclement weather (Burt 1940; Falls 1968), when wind and rain mask the sounds of moving animals. Because collectors most frequently set traps on the ground, the greater trapping success witnessed during rainy weather may result from the tendency of *P. leucopus* to move more on the ground during inclement weather, when sounds they normally make while on this substrate are dampened or masked by the sounds of wind and rain.

The preference by *P. leucopus* for woody litter as a substrate for travel may represent a trade-off between the threat of predation by predators using auditory cues, such as owls, and predation by rattlesnakes (*Crotalus horridus*), which select logs and branches as preferred hunting areas (Reinert et al. 1984). Although rattlesnakes occur in the South Mountain region, none was observed on the study area; however, at least two Barred Owls (*Strix*

varia) and one Screech Owl (*Otus asio*) were heard on or near the study area during nocturnal marking and tracking periods.

Acknowledgments

This study was partially supported by grants from the Miklausen-Likar Research Fund of Shippensburg University. We thank J. E. Maldonado, J. M. Levengood, and D. M. Decker for their assistance in the field. We also thank D. Nagorsen, E. G. Zimmerman and four anonymous reviewers for their constructive comments on earlier drafts of this paper.

Literature Cited

Barry, R. E., Jr., and **E. N. Franq.** 1980. Orientation to landmarks within the preferred habitat by *Peromyscus leucopus*. Journal of Mammalogy 61: 292–303.

Burt, W. H. 1940. Territorial behavior and populations of some small mammals in southern Michigan. Miscellaneous Publications, Museum of Zoology, University of Michigan 45: 1–58.

Falls, J. E. 1968. Activity. Pp. 543-570 *in* Biology of *Peromyscus* (Rodentia). *Edited by* J.A. King. Special Publication, American Society of Mammalogists 2: 1–193.

Graves, S., J. Maldonado, and **J. O. Wolff.** 1988. Use of ground and arboreal microhabitats by *Peromyscus leucopus* and *Peromyscus maniculatus*. Canadian Journal of Zoology 66: 277–278.

Kaufman, G. A. 1989. Use of fluorescent pigments to study social interactions in a small nocturnal rodent, *Peromyscus maniculatus*. Journal of Mammalogy 70: 171–174.

Kirkland, G. L., Jr., T. R. Johnson, Jr., and **P. F. Steblein.** 1985. Small mammal exploitation of a forest-clearcut interface. Acta Theriologica 30: 211–218.

Lemen, C. A. and P. W. Freeman. 1985. Tracking animals with fluorescent pigments: a new technique. Journal of Mammalogy 66: 134–136.

Reinert, H. K, D. Cundall, and **L. M. Bushar.** 1984. Foraging behavior of the timber rattlesnake, *Crotalus horridus*. Copeia 1984: 976–981.

Received 4 February 1991
Accepted 20 February 1992

Extended Longevity in a Large-bodied Stickleback, *Gasterosteus*, Population

T. E. Reimchen

Department of Biology, University of Victoria, P.O. Box 1700, Victoria, British Columbia V8W 2Y2

Reimchen, T. E. 1992. Extended longevity in a large-bodied Stickleback, *Gasterosteus*, population. Canadian Field-Naturalist 106(1): 122–125.

Mark/recapture data combined with counts of pelvic spine annuli on adults of the large-bodied Threespine Stickleback (*Gasterosteus aculeatus*) at Drizzle Lake, Queen Charlotte Islands, demonstrate that adults do not die after the first breeding season (usually 2-3 y of age), as commonly assumed, but can reach 8 y of age. This is almost twice the known maximum age observed in any population within the five genera of Gasterosteidae.

Key Words: Giant stickleback, *Gasterosteus*, growth rate, life span, aging techniques.

The life history of the Threespine Stickleback (*Gasterosteus aculeatus*) is characterized by simple demographic factors including early reproduction and short life span. In most populations, adults range from 1-2 years of age and are 40 to 70 mm standard length (SL). Maximum life span in natural populations does not appear to exceed 4 y (*see* Wootton 1984 for review). On the west coast of North America, but not elsewhere in the circumboreal distribution of the species, Threespine Sticklebacks may reach exceptionally large sizes, with adults averaging 85 mm SL and occasional individuals exceeding 100 mm SL (Moodie 1972; Moodie and Reimchen 1976; Bell 1984). Proximate causes of large size could be extended longevity or possibly accelerated growth rate. In giant sticklebacks, from Mayer Lake, Queen Charlotte Islands, males and females breed during their second year (third summer) and are assumed to die at the end of the first breeding season (Moodie 1984) suggesting accelerated growth and a typical life span.

As part of the ongoing studies of the giant stickleback at Drizzle Lake, Queen Charlotte Islands (Reimchen 1988, 1991), I describe here a substantially divergent pattern of age structure to that known for any other population within the Gasterosteidae.

Methods

Young of the year fish were seined monthly (August to November, 1976; July to September 1977; May to July 1978) while sub-adults and adults were trapped (Gee minnow traps and Fyke net), measured and released bimonthly from 1980 to 1983. Growth rates of young of the year and subadults (< 70 mm) were determined from plots of length frequencies where distinct cohorts could be followed over time. In 1985, randomly sampled adult stickleback (N = 17 033) were marked (spine clip) and released as part of a study on population estimates in the lake (Reimchen 1990). Collections were continued in summers from 1985 to 1990 in which all adult fish were scored for several traits including presence of spine clips. In 1988, recaptures were kept (N = 23) for aging. Otoliths proved unsatisfactory as they were exceptionally opaque. Pelvic spines from each fish were decalcified and embedded in historesin. Thin sections (4-5 microns) were prepared from near the base of the spine and stained with Richardson's solutions (Azure Blue and Methyl Blue 1:1). Annuli were counted under a dissecting microscope. All body size measurements are given in SL.

Results

Fry first appear in the lake in June and are abundant near shore from July to October, ranging from 14 to 25 mm. Juveniles reach 40-45 mm within 12 months and 60-70 mm after 24 months. Very few fish of this size are reproductive (identified by accentuated melanism in males and egg development in females); most breeding adults range from 75 to 85 mm. This suggests that reproduction does not occur until the following spring when fish are approximately 32 months of age.

Table 1. Mark/release and recapture data of 17 033 adults marked in spring 1985 at Drizzle Lake, Queen Charlotte Islands, British Columbia.

Year	Month	Collected	Recaptured	
		N	N	freq
1985	August	2423	635	0.262
1986	May	2065	512	0.199
	August	307	81	0.209
1987	July	1275	160	0.111
1988	June	898	28	0.030
	August	481	12	0.024
1989	June	538	2	0.004
	August	321	2	0.006
1990	July	766	0	0.000

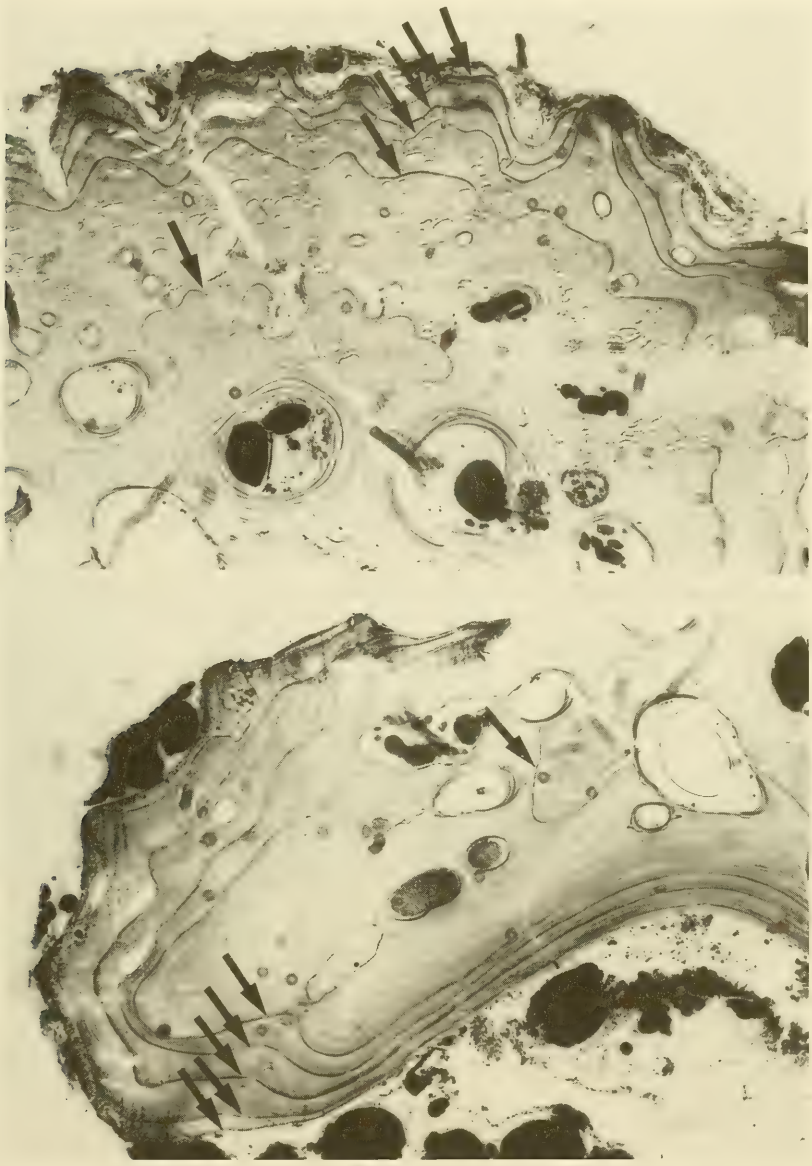


FIGURE 1. Thin-sections of pelvic spines obtained from two sticklebacks marked as adults in spring 1985 and recaptured in June 1988. Each shows six distinct annuli (arrows) and one possible outer annuli. Assuming adults were marked at minimum age (32 months), individuals should have six annuli and be at least 68 months of age.

Sticklebacks do not succumb to mass mortality after their first breeding season. Adult sticklebacks, marked during the breeding season in spring 1985 were recaptured during four successive years (Table 1) indicating a potential life span of 7 y assuming a minimum age of 32 months at the time of marking. High recapture frequencies in spring and summer 1986 demonstrate that the longevity is common. Gradual reduction in recaptures from 1986 to 1990 presumably indicates a loss of the oldest cohorts and continued recruitment of younger fish into the breeding population.

Cross-sections of pelvic spines taken from recaptured fish in 1988 show exceptionally clear annuli (Figure 1). Ages of the recaptures are 5 y (N = 5), 6 y (N = 11), 7 y (N = 5) and 8 y (N = 2) demonstrat-

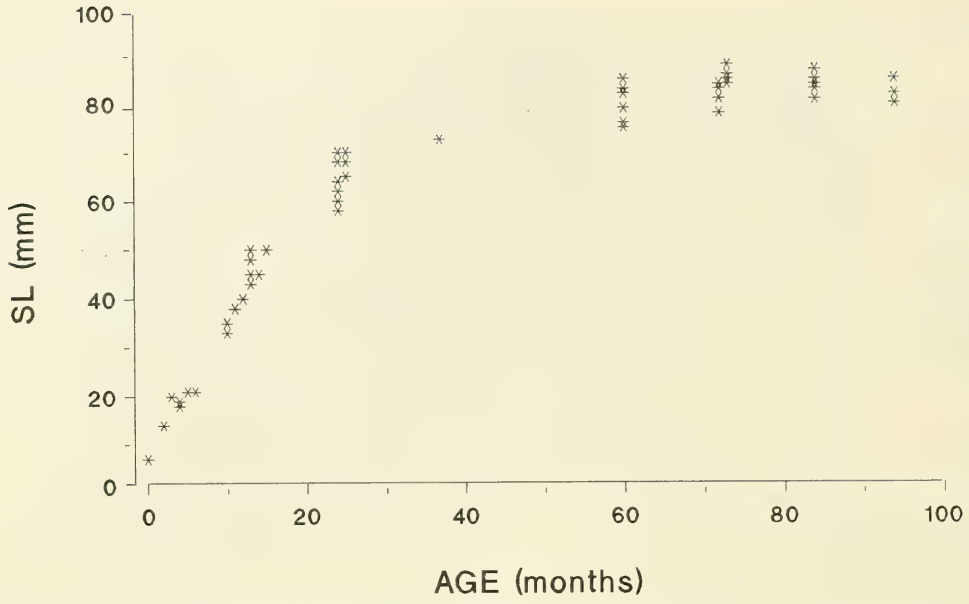


FIGURE 2. Growth rate of Drizzle Lake sticklebacks obtained from length frequency cohorts (<70 mm) and from pelvic spine annuli (> 70 mm).

ing that the original cohort marked in 1985 comprised multiple year classes, possibly with a mode at 3 + y.

Addition of the age/length data from these recaptured fish to length-frequency cohorts of juvenile and sub-adults demonstrates a characteristic asymptotic growth curve with most growth occurring during the first two years (Figure 2). The two oldest fish (8 y) in these samples were 80 mm SL, comparable in size to fast-growing 3 y fish.

Discussion

European and North American studies of body growth in Threespine Sticklebacks show that individuals usually reach 40 mm during the first 12 months with extremes ranging from 30 to 60 mm (Greenbank and Nelson 1959; Wootton 1984). By 24 months, sizes range from a low of 45 mm to a high of 78 mm. In the Drizzle Lake stickleback, mean sizes during the first and second year (42 mm and 65 mm respectively) fall near the average for the species and there is no evidence for accelerated growth. Therefore, the large size at first reproduction (approximately 75 mm) results from prolonged subadult growth. In sticklebacks, this trait has high heritability (McPhail 1977).

Available data from diverse studies indicate that most sticklebacks die after their first breeding season (Wootton 1984). This also appears to apply to the giant stickleback at Mayer Lake (Moodie 1984). Although I am not able to ascertain that the adults in the Drizzle Lake population are breeding each year, the high frequencies of recaptures on successive years clearly indicates that many adults do not die following the first breeding season and have the potential of multiple breeding years (see Reznick and Endler 1982 for discussion of adult size and life history strategy).

Age determination in sticklebacks can be usually made from length frequency distributions and counts of otolith annuli. However, in the Drizzle Lake population, the extended longevity, the small increments of yearly growth and large variability in growth among adults greatly limit the use of length as an estimate of age. Pelvic spine cross-sections had excellent resolving success relative to otoliths and this method may allow for more detailed evaluation of age structure in populations where length frequencies and otoliths are of limited use.

Adult sticklebacks in this locality have a yearly probability near 0.1 of being attacked and escaping from a vertebrate predator (Reimchen 1988). Therefore, the long potential life span greatly extends the period over which predator-prey interactions occur. Any persistent difference in relative fitness among phenotypes could produce a large change in frequency between 3 y old and 8 y old sticklebacks. This may provide an explanation for the striking associations between average vertebral number and adult body size observed in these sticklebacks (Reimchen and Nelson 1987).

Maximum life span of the Threespine Stickleback is geographically variable. In small-bodied populations (30-50 mm), individuals generally die prior to their second winter while in larger-bodied populations (50-90 mm), sticklebacks may survive for 3 y

and occasionally 4 y (Greenbank and Nelson 1957; Aneer 1973). The oldest age recorded for any of the other four genera in Gasterosteidae is 5 y, found in *Pungitius pungitius* (Wootton 1984). Clearly, the Threespine Sticklebacks in Drizzle Lake which reach at least 8 y of age are exceptional in the taxon. However, since this is the first study involving long term collections of a marked population of sticklebacks, it is plausable that extended longevity will be found elsewhere if increased attention is given to multiple year sampling.

Acknowledgments

I thank S. D. Douglas for field assistance, T. Jacobsen, P.O'Reilly, and J. Westley for technical assistance and the Ecological Reserves Branch, Ministry of Parks, Government of British Columbia for permission to work on the Drizzle Lake Reserve. This work was supported by an NSERC grant (A2354) to the author.

Literature Cited

Aneer, G. 1973. Biometric characteristics of the three-spined stickleback (*Gasterosteus aculeatus* L.) from the Northern Baltic proper. Zoologica Scripta 2: 157–162.

Bell, M. A. 1984. Gigantism in threespine stickleback: implications for causation of body size evolution. Copeia 1984: 530–534.

Greenbank, J., and **P. R. Nelson.** 1959. Life-history of the three-spine stickleback *Gasterosteus aculeatus* Linnaeus in Karluk Lake and Bare Lake, Kodiak Island, Alaska. United States Fish and Wildlife Service Bulletin No. 153.

McPhail, J. D. 1977. Inherited interpopulation difference in size at first reproduction in threespine stickleback, *Gasterosteus aculeatus* L. Heredity 38: 53–60.

Moodie, G. E. E. 1972. Morphology, life history and ecology of an unusual stickleback (*Gasterosteus aculeatus*) in the Queen Charlotte Islands, Canada. Canadian Journal of Zoology 50: 721–732.

Moodie, G. E. E. 1984. Status of the Giant (Mayer Lake) Stickleback, *Gasterosteus* sp., on the Queen Charlotte Islands, British Columbia. Canadian Field-Naturalist 98: 115–119.

Moodie, G. E. E., and **T. E. Reimchen.** 1976. Phenetic variation and habitat differences in *Gasterosteus* populations of the Queen Charlotte Islands. Systematic Zoology 25: 49–61.

Reimchen, T. E. 1988. Inefficient predators and prey injuries in a population of giant stickleback. Canadian Journal of Zoology 66: 2036–2044.

Reimchen, T. E. 1990. Size-structured mortality in a threespine stickleback (*Gasterosteus aculeatus*) - cutthroat trout (*Oncorhynchus kisutch*) community. Canadian Journal of Fisheries and Aquatic Sciences 47: 1194–1205.

Reimchen, T. E. 1991. Trout foraging failures and the evolution of body size in stickleback. Copeia 1991: 1098–1104.

Reimchen, T. E., and **J. S. Nelson.** 1987. Habitat and morphological correlates to vertebral number as shown in a teleost, *Gasterosteus aculeatus*. Copeia 1987: 868–874.

Reznick, D. and **J. A. Endler.** 1982. The impact of predation on life history evolution in Trinidadian guppies (*Poecilia reticulata*). Evolution 36: 160–177.

Wootton, R. J. 1984. A functional biology of sticklebacks. University of California Press, Berkeley and Los Angeles. 265 pages.

Received 18 March 1991
Accepted 20 February 1992

Notes

Two Wolves, *Canis lupus*, Killed by a Moose, *Alces alces*, in Jasper National Park, Alberta

J.L. Weaver[1,2], C. Arvidson[2], and P. Wood[2]

[1]School of Forestry, University of Montana, Missoula, Montana 59812
[2]Northern Rockies Conservation Cooperative, P.O. Box 2705, Jackson, Wyoming 83001

Weaver, J. L., C. Arvidson, and P.Wood. 1992. Two Wolves, *Canis lupus*, killed by a Moose, *Alces alces*, in Jasper National Park, Alberta. Canadian Field–Naturalist 106(1): 126–127.

An adult female Moose (*Alces alces*) killed two adult male Wolves (*Canis lupus*) in northeastern Jasper National Park, Alberta, in July 1989. Moose here are uncommon and very localized, but this incident occurred within 5 km of the Wolves' rendezvous site. This observation further establishes Moose as dangerous prey for Wolves.

Key Words: Wolf, *Canis lupus*, Moose, *Alces alces*, predation risk.

Wolves (*Canis lupus*) risk injury and death in attempting to kill large prey (Mech 1970). Approximately 25% of 1450 Wolves killed by humans in control programs in Alaska (calculated from Rausch (1967) and Phillips (1984)) showed traumatic skull injuries, presumably inflicted by Moose (*Alces alces*) and other large prey. The likelihood of finding Wolves hurt or killed by prey is so low, however, that few instances have been reported (*see* Mech and Nelson 1990). This note provides information about two Wolves killed by a Moose.

On 23 July, 1989, we discovered the remains of two adult male Wolves and an adult female Moose at a predation site (53°11'30"N, 117°59'30"W) in northeastern Jasper National Park, Alberta. The encounter occurred on level ground in a backwater floodplain forest of White Spruce (*Picea glauca*) (Holland and Coen 1983).

Wolf A, age estimated from cementum annuli of a canine (Goodwin and Ballard 1985) at 8–10 years (G. Matson, personal communication, on all age estimations), was found floating in a beaver pond (approximately 0.5 ha and 2 m at maximum depth) about 15 m from the Moose carcass. Decomposition had been retarded because the carcass was partially submerged. This Wolf had several thoracic contusions, a fractured scapula and healed rib fractures on each side of the rib cage from previous injuries. Wolf B, age estimated from cementum annuli of a canine at 2–3 years, lay on the ground about 40 m from the Moose carcass and was partially decomposed. No cranial injuries were apparent on either wolf. Based upon subsequent decomposition of Wolf A's carcass on land and other observations of the Wolf pack, we estimated the fatal encounter to have occurred 7–10 days previously.

Four remaining adult Wolves of the pack had consumed > 90% of the Moose, age estimated from cementum annuli of a lower incisor (Gasaway et al. 1978) at 13 years. It is reasonable to presume that these Wolves were present during the encounter. Neither of the dead Wolves appeared to have been consumed by other Wolves. There was no evidence of a calf Moose in the vicinity nor of any skeletal abnormalities with the adult Moose.

The encounter occurred approximately 5 km from a rendezvous site occupied by the Wolves. Systematic sampling of ungulate pellet groups on 1-km^2 sample units (*see* Freddy and Bowden 1983) randomly selected within a 10-km radius of the Wolves' rendezvous site revealed that Moose occurred on 5.0% of 40 sample units (distribution) and comprised 3.3% of all ungulate pellet groups (relative abundance) during summer (Weaver, unpublished data). Deer (*Odocoileus hemionus* and *O. virginanus*) and Elk (*Cervus elaphus*) occurred on 72.5% and 30.0% of the sample units and comprised 59.3% and 36.0% of all pellet groups, respectively.

Thirteen prey-caused mortalities of wolves are reported in the literature (MacFarlane 1905; Stanwell-Fletcher 1942; Savile and Oliver 1964; Frijlink 1977; Crawford 1980; Nelson and Mech 1985; Ballard et al. 1987; Pasitschniak-Arts et al. 1988; Mech and Nelson 1990; this note). Albeit a small sample, it is interesting to note the following aspects:

(1) Seven of the 12 incidents involved Moose; three, White-tailed Deer; and two, Muskox (*Ovibos*

moschatus). Phillips (1984) reported that 23% of 171 Wolf skulls from areas in Alaska with Moose displayed traumatic skull injuries whereas only 11% of 18 Wolf skulls from areas without Moose had such injuries.

(2) Of the six fatal encounters with prey for which the sex of the injured Wolves was reported, five of the seven Wolves killed were adult males (Stanwell-Fletcher 1942; Mech and Nelson 1990; this note). Phillips (1984) reported that 24% of 95 male Wolf skulls suffered traumatic skull injuries compared with 19% of 96 female Wolf skulls. Peterson and Page (1988) noted that a malnourished Wolf with both recent and old rib fractures found near a Moose carcass was an adult male.

(3) In at least three encounters, the injured Wolves were part of a pack (3-11 other Wolves) attacking the prey (Frijlink 1977; Crawford 1980; Nelson and Mech 1985).

(4) Fatal encounters have occurred in both winter (three Moose, two White-tailed Deer) and summer (three Moose, one White-tailed Deer).

This note and the previous reports establish that large prey, particularly Moose, are dangerous and pose risk of injury and fatality to Wolves. This small collection of evidence is consistent with a hypothesis that risk to Wolves increases with prey size. Several Wolf–Moose studies (Mech 1966; Peterson 1977; Peterson et al. 1984) have shown that Wolves often decide to search for less risky opportunities rather than to attack such dangerous prey (Stephens and Krebs 1986; Forbes 1989).

Acknowledgments

Financial support for the Wolf field study in Jasper National Park was provided by National Fish and Wildlife Foundation, National Audubon Society, J. Murphy, Defenders of Wildlife, and C. Patrick. We thank R. O. Peterson, M. K. Phillips, D. H. Pletscher, and W. O. Pruitt for helpful reviews.

Literature Cited

Ballard, W. B., J. S. Whitman, and **C. L. Gardner.** 1987. Ecology of an exploited wolf population in south–central Alaska. Wildlife Monograph 98. 54 pages.

Crawford, J. S. 1980. Wolves, bears, and bighorns. Alaska Northwest Publishing Company, Anchorage. 175 pages.

Forbes, L. S. 1989. Prey defences and predator handling behavior: the dangerous prey hypothesis. Oikos 55: 155–158.

Freddy, D. J., and **D. C. Bowden.** 1983. Sampling mule deer pellet–group densities in juniper–pinyon woodland. Journal of Wildlife Management 47: 476–485.

Frijlink, J. H. 1977. Patterns of wolf pack movements prior to kills as read from tracks in Algonquin Provincial Park, Ontario, Canada. Bijdragen Tot De Dierkunde 47: 131–137.

Gasaway, W. C., D. B. Harkness, and **R. A. Rausch.** 1978. Accuracy of moose age determinations from incisor cementum layers. Journal of Wildlife Management 42: 558–563.

Goodwin, E. A., and **W. B. Ballard.** 1985. Use of tooth cementum for age determination of gray wolves. Journal of Wildlife Management 49: 313–316.

Holland, W. D., and **G. M. Coen.** *Editors.* 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Institute of Pedology, University of Alberta, Edmonton. Publication Number SS–82–44. 540 pages.

MacFarlane, R. R. 1905. Notes on Mammals collected and observed in the northern Mackenzie River district, Northwest Territories of Canada. Proceedings of the United States National Museum 29: 673–764.

Mech, L. D., 1966. The wolves of Isle Royale. U.S. National Park Service Fauna Series Number 7. 2120 pages.

Mech, L. D. 1970. The wolf: the ecology and behavior of and endangered species. Natural History Press, New York. 384 pages.

Mech, L. D., and **M. E. Nelson.** 1990. Evidence of Prey–caused mortality in three wolves. American Midland Naturalist 123: 207–208.

Nelson, M. E., and **L. D. Mech.** 12985. Observation of a wolf killed by a deer. Journal of Mammology 66: 187–188.

Pasitschniak–Arts, M., M. E. Taylor, and **L. D. Mech.** 1988. Skeletal injuries in an adult arctic wolf. Arctic Alpine Research 20: 360–365.

Peterson, R. O. 1977. Wolf ecology and prey relationships on Isle Royale. U.S. National Park Service Science Monograph Series Number 12. 210 pages.

Peterson, R. O., and **R. E. Page.** 1988. The rise and fall of Isle Royal wolves, 1975–9186. Journal of Mammalogy 69: 89–99.

Peterson, R. O., J. D. Wollington, and **T. N. Bailey.** 1984. Wolves of the Kenai Peninsula, Alaska. Wildlife Monographs No. 88. 52 pages.

Phillips, M. K. 1984. The cost to wolves of preying on ungulates. Australian Mammalogy 8:99.

Rausch, R. A. 1967. Some aspects of the population ecology of wolves, Alaska. American Zoologist 7: 253–265.

Savile, D. B. O., and **D. R. Oliver.** 1964. Bird and mammal observations at Hazen Camp, Northern Ellesmere Island, in 1962. Canadian Field-Naturalist 78: 1–7.

Stanwell–Fletcher, J. F. 1942. Three years in the wolves' wilderness. Natural History 49: 136–147.

Stephens, D. W., and **J. R. Krebs.** 1986. Foraging theory. Princeton University Press, Princeton, New Jersey. 247 pages.

Received 26 November 1990
Accepted 21 February 1992

Brown Bear, *Ursus arctos middendorffi*, Predation on a Trumpeter Swan, *Cygnus buccinator*, Nest

PAUL HENSON AND TODD A. GRANT

Department of Fisheries and Wildlife, 200 Hodson Hall, University of Minnesota, St. Paul, Minnesota 55108.

Henson, Paul, and Todd A. Grant. 1992. Brown Bear, *Ursus arctos middendorffi*, predation on a Trumpeter Swan, *Cygnus buccinator*, nest. Canadian Field-Naturalist 106(1): 128–130.

An adult Brown Bear (*Ursus arctos middendorffi*) was recorded by timelapse movie camera preying upon a Trumpeter Swan (*Cygnus buccinator*) nest on the Copper River Delta, Alaska, in 1989. An adult swan charged the bear and attempted to defend the nest but was unsuccessful. To our knowledge this film is the only photographic documentation of an encounter between Trumpeter Swans and a large mammalian predator.

Key Words: Brown Bear, *Ursus arctos middendorffi,* Trumpeter Swan, *Cygnus buccinator*, antipredator, behavior, nest predation.

Bear predation of geese and swans is believed to be an uncommon occurrence, and there are only a few published descriptions in the North American literature (Barry 1964; Abraham et al. 1977; Madsen et al. 1989). This paper documents a Brown Bear (*Ursus arctos middendorffi*) attack on a Trumpeter Swan (*Cygnus buccinator*) nest. We have been unable to find any published accounts of interactions between Trumpeter Swans and Brown Bears, and there are no descriptions of Trumpeter Swan defensive behavior in the face of such a threat. Almost all Trumpeter Swan predation observations have been made after the predation occurred by reading available sign such as egg shell or carcass remains (Banko 1960; Hansen et al. 1971). The predation reported here was recorded by timelapse movie camera, thus allowing a detailed description of the encounter.

Study Area and Methods

Trumpeter Swans were observed on the Copper River Delta, located adjacent to eastern Prince William Sound, Alaska, between 60° and 60°30'N latitude and 144°W longitude. Observation blinds and Minolta 401 timelapse movie cameras were placed at six swan nesting wetlands. The described attack occurred at an observation territory (T289) located 28 km along the Copper River Highway from the town of Cordova. The observation blind and timelapse movie camera at this territory were placed on a hill 135 m north of the nest mound and were concealed behind fir trees and shrubs. The camera's field of view included 30 m on both sides of the nest and about 100 m both in front of and behind it. Each film roll lasted about 2.5 days with an exposure interval of one frame per minute. Researchers observed the pair on 31 days from 15 April – 11 July 1989. Camera observations were made continuously from 11 April – 29 May 1989. The male swan in this pair was marked in 1988 with a blue plastic neckband.

Results

The Brown Bear attack took place on 28 May 1989, commencing at 07:42 hours and lasting approximately 11 minutes. It is unknown how many eggs were in the nest at the time of the encounter. The following is a description of events recorded by the camera:

07:42 – Incubating female is in sleeping position but assumes head-up alert posture for the next 4 minutes; male swan is not visible.

07:46 – Female takes a defense recess, described by Cooper (1979) as a rapid exit from the nest after assuming alert posture and not covering the eggs prior to departure. The male is still not visible.

07:48 – A swan of unknown sex appears approximately 2 m from the nest. (The neck-collar is not visible due to splashed water, but this swan is believed to be the male based on other behavioral observations made during this study.) It assumes a head-up alert posture, and places itself between the nest and the direction from which the bear (still off-frame) is approaching.

07:49 – The Brown Bear is now within 3 m of the nest. The visible swan appears to have charged within striking distance of the bear. Its wings are spread and water is splashed in the air.

07:50 – The bear is atop the nest mound with its head in the nest cup, presumably feeding on the eggs. The swan is about 3 m away from the nest, displaying in a defensive posture with spread wings towards the bear (Hansen et al. 1971).

07:51 – The bear is still feeding, and the swan in head–up alert posture is present but no longer displaying with its wings.

07:53 – The bear has left the nest mound and no swans are visible for the next 11 minutes.

08:04 – One swan is at the mound; for the next 23 minutes both swans swim around the nest area 20 m or less from the nest mound.

08:27 – One swan climbs atop the mound for 1 minute. During the rest of this day both birds spend most of their time on or near the mound. Preening, nestbuilding, and feeding behaviors are observed.

We arrived at this wetland two days after the attack, and a visit to the mound was made upon realizing that the clutch had been lost and the adults were no longer attending the nest. Only a few egg shell fragments were found in the nest cup, consistent with the observations of Hansen et al. (1971) that Trumpeter eggs taken by bears are usually eaten in their entirety. One side of the mound appeared to have been dug away; this hole may have been excavated by the bear during the attack, or by the swans during post-predation nest construction activities.

Post-predation time budget observations of this swan pair were conducted on 12 separate days during the next 1.5 months, resulting in 79.7 hours of observation time. The pair made no obvious renesting attempt. The male did engage in some nest construction behavior and three copulations were observed, one each on the three observation days (30 May, 2 June, 9 June) immediately following the predation. The time budgets of both swans following the loss of the clutch were similar to those of swans during the prelaying period of the breeding season (P. Henson, unpublished data). The female, now no longer incubating, increased her time spent feeding and approached levels reached during the prelaying and laying phases. Male feeding remained essentially unchanged, and both sexes increased the time spent preening. Both sexes also increased their sleeping times, the female sleeping more than the male and more than she did during the pre-incubation phase of the breeding season.

Discussion

To our knowledge, this film is the only photographic documentation of an encounter between Trumpeter Swans and a large mammalian predator. Banko (1960) described one bear attack (species unknown) on an adult Trumpeter Swan in Yellowstone National Park, Wyoming. Hansen et al. (1971) documented three attacks on Trumpeter Swan nests by either Brown Bears or Black Bears (*Ursus americanus*) on the Copper River Delta. These interactions were all described from nest remains.

Predation by both Brown and Black bears is believed to be a major factor in the decline of the Dusky Canada Goose (*Branta canadensis occidentalis*) in the Copper River area (Cornely et al. 1985; B. H. Campbell, unpublished manuscript, Alaska Department of Fish and Game, Anchorage, 1986), but it does not appear to be having a similar effect on the delta's Trumpeter Swan population. This population has been relatively stable over the last 11 years (D. J. Groves, B. Conant, R. J. King, and K. Giezentanner, unpublished manuscript, U.S. Fish and Wildlife Service, Juneau, 1990). Bears may have less impact on the Trumpeter Swan population because of a combination of three factors: **1)** the well–dispersed nest locations on the Copper River Delta, a density that is maintained by agonistic behavior and a general intolerance of conspecifics on the nesting wetlands during the breeding season (Banko 1960; Hansen et al. 1971; this study); **2)** the habit of constructing large, cone–shaped nest mounds made of rhizomes and stems of *Carex* spp., *Potentilla* spp., and *Equisetum* spp., in deep water away from the shoreline (Dusky Canada Geese, by contrast, are upland nesters and may be more vulnerable to terrestrial predators [Cornely et al. 1985]); and **3)** the large size and aggressive defensive behavior of Trumpeter Swans towards intruders and potential predators (Banko 1960; De Vos 1964; Hansen et al. 1971; this study).

Trumpeter Swans are territorial birds that defend their nesting wetlands from most types of avian and mammalian predators (Banko 1960; De Vos 1964; Hansen et al 1971; Kear 1972). They do exhibit different response patterns and aggressive displays to different types of predators. Our observations suggest that female swans will defend against avian predators but they usually leave the nest and hide in vegetation when threatened by humans or other large mammals (Henson and Grant 1991). The male, however, seems to defend the nest against all types of predators if the nest is approached directly. It is impossible to be sure of exactly what happened between the swan and the bear due to the one-minute interval between frames of the timelapse film, but the aggressive behaviors displayed during the attack appear to be consistent with those exhibited when Trumpeters and other swans are disturbed by humans and other mammals, such as Moose (*Alces alces*), Arctic Fox (*Alopex lagopus*), Red Fox (*Vulpes vulpes*), and domestic dogs (Banko 1960; De Vos 1964; Hansen et al. 1971; Evans 1975; Hawkins 1986). Such responses probably put the defending swan at considerable risk when protecting eggs or cygnets against larger predators, but the strategy may sometimes pay off when swans are confronted by bears. A biologist on the Copper River Delta observed a nesting swan pair successfully defend against a Brown Bear (estimated weight 400 kg); both birds in the pair beat their wings against the swimming bear and forced it away from their nest (personal communication, K. Giezentanner, U.S. Forest Service, Cordova, Alaska). In contrast, only one swan participated in the defense recorded by our camera.

Trumpeter Swans in captivity have produced second clutches after the first eggs were removed, but the probability of wild northern swans renesting is low due to the shortness of the breeding season (Kear 1972). The loss of the eggs at T289 occurred approximately one week prior to expected hatch, and successful renesting would have been very unlikely. No eggs are believed to have been laid after the loss, but copulations were observed on each of three

observation days during the next two weeks. By contrast, a post–hatch copulation was observed only once among the seven other swan pairs that successfully hatched cygnets during the 1988 and 1989 seasons. The post-predation copulations suggest that renesting may have been attempted had the predation occurred earlier in the season.

Acknowledgments

We thank the University of Minnesota and the U. S. Forest Service, Cordova Ranger District, for funding this study. Additional support was provided by the Trumpeter Swan Society, the Minnesota Waterfowl Association, and the Dayton Natural History Fund of Bell Museum of Natural History, University of Minnesota. J. Sovall helped collect data. Thanks to K.F. Abraham, C. M. Baggot, F.J. Cuthbert, and D.F. McKinney for reviewing the manuscript. Special thanks to J. A. Cooper for advice and support.

Literature Cited

Abraham, K. F., P. Mineau, and **F. Cooke**. 1977. Unusual predators of Snow Goose eggs. Canadian Field–Naturalist 91: 317–318.

Banko, W. E. 1960. The Trumpeter Swan: its history, habits, and population in the United States. North American Fauna 63. U. S. Fish and Wildlife Service, Washington, D.C. 214 pages.

Barry, T. W. 1964. Brant, Ross' Goose, and Emperor Goose. Pages 145–154 *in* Waterfowl Tomorrow. *Edited by* J. P. Linduska. U.S. Fish and Wildlife Service, Washington, D.C. 770 pages.

Cooper, J. A. 1979. Trumpeter Swan nesting behaviour. Wildfowl 30: 55–71.

Cornely, J. C., B. H. Campbell, and **R. L. Jarvis.** 1985. Productivity, mortality. and population status of Dusky Canada Geese. Transactions of the North American Wildlife Natural Resources Conference 50: 540–548.

De Vos, A. 1964. Observations on the behaviour of captive Trumpeter Swans during the breeding season. Ardea 52: 166–189.

Evans, M. E. 1975. Breeding behaviour of captive Bewick's Swans. Wildfowl 26: 117–130.

Hansen, H. A., P. E. K. Shepard, J. G. King, and **W. A. Troyer**. 1971. The Trumpeter Swan in Alaska. Wildlife Monograph 26. 83 pages.

Hawkins, L. L. 1986. Nesting behaviour of male and female Whistling Swans and implications of male incubation. Wildfowl 37: 5–27.

Henson, P., and **T. A. Grant.** 1991. The effects of human disturbance on Trumpeter Swan breeding behavior. Wildlife Society Bulletin 19: 248–257.

Kear, J. 1972. Reproduction and family life. Pages 79–124 *in* The Swans. *Edited by* P. Scott. Houghton Mifflin Co., Boston, Mass. 242 pages.

Madsen, J., T. Bregnballe, and **F. Mehlum**. 1989. Study of the breeding ecology and behaviour of the Svalbard population of Light–bellied Brant Goose *Branta bernicla hrota*. Polar Research 7: 1–21.

Received 4 April 1991
Accepted 17 February 1992

Yellow-bellied Marmot, *Marmota flaviventris*, Predation on Pikas, *Ochotona princeps*

JIM R. PETTERSON

Northwest Alaska Areas National Parks, Box 1029, Kotzebue, Alaska 99752

Petterson, Jim R. 1992. Yellow-bellied Marmot, *Marmota flaviventris,* Predation on Pikas, *Ochotona princeps*. Canadian Field-Naturalist 106(1): 130–131.

Evidence is presented that suggests Yellow-bellied Marmots (*Marmota flaviventris*) prey on pikas (*Ochotona princeps*) in the Sierra Nevada Mountains of California.

Key Words: *Marmota flaviventris*, Yellow-bellied Marmot, *Ochotona princeps*, Pika, predation, infanticide, California.

Yellow-bellied Marmots (*Marmota flaviventris*) and Pikas (*Ochotona princeps*) are common inhabitants of alpine habitats in the mountains of western United States. Both are considered to be herbivores, eating primarily grasses and forbs that grow among the boulders of talus slopes (Ivins and Smith 1983; Carey 1985). Although these two sympatric species are among the most numerous and frequently seen small herbivores in alpine habitats, ecological relationships between them are largely unexplored. Recent work, however, indicates that Pikas may derive energetic benefits from marmots by using marmot scats to supplement food stores (Gessaman and Goliszek 1989). Coexistence with marmots may not be without risk however; herein I will describe observations from King's Canyon National Park, California, that suggest Pikas run the risk of predation by marmots.

While traversing a dry, southwest-facing, alpine talus slope in Sphinx Lakes basin (elevation

3 500 m) at 1800 h on 10 July, 1989, I heard a short alarm call emitted by a Pika concealed beneath large boulders that were scattered across the mountainside. I noticed 30 sec later a Yellow-bellied Marmot about 15 m away emerging from the rocks carrying a juvenile Pika in its mouth. The marmot shook the Pika vigorously from side-to-side two or three times, then proceeded to tear apart the Pika with its teeth. Because it was possible to see blood and viscera dripping from the Pika, I inferred that it had been freshly killed or had died very recently. After observing the marmot for about four minutes, it ran upslope and disappeared under the rocks, still carrying the Pika. I searched the immediate area for any additional evidence and found a different dead juvenile Pika lying on the rocks approximately 50 m downslope from where the marmot had vanished. The Pika carcass had been eviscerated, and appeared to have been dead for at least two days, because it was desiccated and fly larvae were present in the carcass. It was not known if the observed marmot had been responsible for the death of this Pika or if it had merely scavenged it.

Marmots, like other ground squirrels and chipmunks, are known to utilize carrion (personal observations; Frase and Hoffman 1980; Bintz 1984). Cannibalism and infanticide have also been observed for marmots (Armitage et al. 1979; Brody and Melcher 1985). Possible causes of infanticide include competition and/or nutrition; but the relative importance of each factor is poorly known currently.

Predation by marmots may simply be an extension of infanticide to interspecific circumstances. Another possible explanation is that predation by marmots on Pikas may reflect interference competition taken to an extreme. A recent study in Arctic Canada substantiated that Arctic Ground Squirrels (*Spermophilus parryii*) kill and consume Collared Lemmings (*Dicrostonyx kilangmiutak*) (Boonstra et al. 1990).

For herbivores, protein and other nutrients are generally more limiting than energy (White 1978). In Colorado, marmots consumed only 6% of available net primary production in summer (Frase and Armitage 1989). Assuming energy is not limiting for marmots and Pikas, another possible explanation for marmot predation on Pikas involves protein availablilty. Decreases in the protein content of vegetation during the latter periods of the growing season may prompt opportunistic predatory behavior by marmots to supplement low protein intake. The existence of predator-prey interactions between marmots and Pikas would add considerable complexity to competitive relationships and energy transfer in alpine systems.

Acknowledgments

I thank D. Van Vuren for helpful suggestions given on an earlier draft, and the constructive comments of two anonymous reviewers.

Literature Cited

Armitage. K. B., D. W. Johns, and **D. C. Andersen**. 1979. Cannibalism among yellow-bellied marmots. Journal of Mammalogy 60: 205–207.

Bintz, G. L. 1984. Water balance, water stress, and the evolution of seasonal torpor in ground-dwelling sciurids. Pages 142–165 *in* The biology of ground dwelling squirrels. *Edited* by J.O. Murie and G. R. Michener. University of Nebraska Press, Lincoln, Nebraska.

Boonstra, R., C. J. Krebs, and **M. Kanter.** 1990. Arctic ground squirrel predation on collared lemmings. Canadian Journal of Zoology 68: 757–760.

Brody, A. K., and **J. Melcher**. 1985. Infanticide in Yellow-bellied marmots. Animal Behavior 33: 673–674.

Carey, H.V. 1985. Nutritional ecology of yellow-bellied marmots in the White Mountains of California. Holarctic Ecology 8: 259–264.

Frase, B. A., and **K. B. Armitage.** 1989. Yellow-bellied marmots are generalist herbivores. Ethology, Ecology and Evolution 1: 353–366.

Frase, B. A., and **R. S. Hoffman**. 1980. *Marmota flaviventris*. Mammalian Species Number 135: 1–8.

Gessaman, J. A., and **A. G. Goliszek**. 1989. Marmot scats supplement hay pile vegetation as food energy for pikas. Great Basin Naturalist 49: 466–468.

Ivins, B. L., and **A. T. Smith**. 1983. Responses of pikas to naturally occurring terrestrial predators. Behavioral Ecology and Sociobiology 13: 277–285.

White, T. C. R. 1978. The importance of a selective shortage of food in animal ecology. Oecologia 33: 71–86.

Received 15 April 1991
Accepted 21 February 1992

Two Rare Mosses from British Columbia

RICHARD D. REVEL

Environmental Science Programme, Faculty of Environmental Design, University of Calgary, Calgary, Alberta T2N 1N4

Revel, Richard D. 1992. Two rare mosses from British Columbia. Canadian Field-Naturalist 106(1): 132.

The bryophyte *Steerecleus serrulatus* (Hedw.) Robins. is reported as an addition to the British Columbia moss flora while *Myrinia pulvinata* (Wahlenb.) Schimp. constitutes an important record for a very rare species.

Key Words: *Myrinia, Steerecleus, Rhynchostegium*, British Columbia, bryophytes.

While conducting phytosociological investigations in the Sub-boreal Spruce Biogeoclimatic Zone of north-central British Columbia (Revel 1972) two mosses of considerable bryological interest were encountered. *Myrinia pulvinata* (Wahlenb.) Schimp. is a very rare bryophyte in British Columbia while *Steerecleus serrulatus* (Hedw.) Robins. represents an addition to the British Columbia moss flora.

Myrinia pulvinata has previously been reported from scattered locations in northern, western and eastern Europe, the Tyrol, Italy, Siberia and Canada (Nyholm 1960). Nyholm reports that the species occurs in wet or moist habitats and occasionally on submerged tree trunks. The species was first reported from British Columbia from near McLeod Lake and Hudson Hope as *Leskea pulvinata* Wahl. by Macoun (1892) but has not been reported from the province since that time. This record, from the same general area as Macoun's collection, is a reaffirmation of its presence in British Columbia.

The present collection was made in a plant community dominated by *Alnus tenuifolia, Matteuccia struthiopteris* and *Urtica lyallii* along the eastern shore of McLeod Lake. *Myrinia* occured as a basal epiphyte on *Alnus tenuifolia* Nutt. The plant community is characterised by annual flooding, burried A-C soil profiles due to the flooding and very high organic matter decomposition rates. It is widely distributed along the floodplains of lakes and streams in the Sub-boreal Biogeoclimatic Zone.

The present record of *Steerecleus serrulatus* (Hedw.) Robins. represents an addition to the British Columbia moss flora and formed the basis for the species report from British Columbia (Ireland et al. 1987). The species has previously been collected in Washington state, Nebraska, Missouri, Texas, Lousiana, Mississippi, Ohio, Ontario, Quebec and from New England south to Florida where it is usually found on humus (Lawton 1971).

The present record of *Steerecleus* formed a very minor component of the moss layer in a plant community dominated by *Gymnocarpium dryopteris, Oplopanax horridus, Abies lasiocarpa* and *Picea glauca* where it was found growing both on humus and as a basal epiphyte on *Populus tremuloides*. This plant community is distributed on eutrophic alluvial terraces or seepage sites at the base of slopes throughout the Sub-boreal Biogeoclimatic Zone and is the most productive forest community in the area.

Comprehensive phytosociological and environmental information is available on the plant communities in which the two species were found (Revel 1972). Revel (1972) refers to *Steerecleus* as *Rhynchostegium serrulatum* (Hedw.) Jaeg. & Sauerb.

Voucher specimens of *Myrinia pulvinata* (Revel No. 69060906) and *Steerecleus serrulatus* (Revel No. 690711) are housed in the herbarium, University of British Columbia (UBC).

Literature Cited

Ireland, R. R., G. R. Brassard, W. B. Schofield, and **D. H. Vitt.** 1987. Checklist of the Mosses of Canada II. Lindbergia 13: 1-62.

Lawton, Elva. 1971. Moss flora of the Pacific Northwest. Hattori Botanical Labratory. Nichinan, Japan. 362 pages.

Macoun, J. 1892. Catalogue of Canadian Plants. Part IV-Musci (page 170). Printed for the Government of Canada by William Foster Brown & Company. Montreal. 295 pages.

Nyholm, Elsa. 1960. Illustrated Moss Flora of Fennoscandia: II Musci, Fascicle 4 (page 406). Lund, Sweden.

Revel, R. D. 1972. Phytogeocoenoses of the Sub-boreal Spruce Biogeoclimatic Zone in North Central British Columbia. Ph.D. Thesis. Department of Botany, University of British Columbia, Vancouver, B.C. 409 pages.

Received 25 July 1991
Accepted 17 February 1992

White- and Pink-flowered *Cichorium intybus*, Blue-flowered Chicory, from British Columbia

RICHARD D. REVEL

Environmental Science Programme, Faculty of Environmental Design, University of Calgary, Calgary, Alberta T2N 1N4

Revel, Richard D. 1992. White- and pink-flowered *Cichorium intybus*, Blue-flowered Chicory, from British Columbia. Canadian Field-Naturalist 106(1): 133.

Key Words: Blue-flowered Chicory, *Chichorium intybus*, Asteraceae, white-flowered, pink-flowered, phytogeography, British Columbia.

Cichorium intybus L., Blue-flowered Chicory, an introduced Eurasian weed, grows along roadsides in limited areas throughout North America where the colour of its flower heads are usually blue. This note provides a review and specific records of two rare forms of *C. intybus* and should be of interest to both the naturalist and the professional botanist.

During botanical investigations in the North Okanagan-Shuswap area of British Columbia in the summer of 1990, separate small populations of this species comprised of individuals with either pink or white flowers were observed growing freely among abundant stands of blue-flowered plants. The white-flowered form was collected near the intersection of the Gardam Lake road with Highway 97, approximately 6 miles north of Enderby, B.C., whereas both forms were found on the east side of Mara lake approximately 4 miles south of Sicamous, B.C., on Highway 97. As I have botanized in this area for many years and never observed this variation in flower colour it seemed appropriate to review the literature and examine herbarium specimens to determine how common such pink-flowered and white-flowered forms are.

Approximately 30 herbarium specimens representing collections from Alberta, British Columbia, Denmark, Illinois, New Brunswick, and Quebec were examined at the University of Calgary Herbarium (UAC). All specimens had blue flowers and no collectors' notes indicated that anything other than blue flowers were present.

Eleven local and international floras were consulted on the matter of flower cololur in the species. Budd and Best (1969) and Looman and Best (1979) mention only the presence of blue flowers from the Canadian prairies. Munz (1959) from California, Hitchcock et al. (1955) from the Pacific Northwest, and Taylor and MacBryde (1977) and Clark (1973) from British Columbia indicate that flowers are blue and occasionally or rarely white. No mention is made about pink flowers by the previous authors. Moss (1959) in Alberta, Bailey (1949) in the *Manual of Cultivated Plants of North America,* Polunin (1969) from Europe, Frankton (1967) writing on the weeds of Canada and Scoggan (1979) in the *Flora of Canada* all make mention of pink and white forms of *C. intybus* L. although they clearly state that such forms are either rare or at best occasional.

Of the above floras, the most instructive pertaining to flower colour was Scoggan (1979), who noted that plants with pink flowers were described as *C. intybus* L. forma *roseum* Neum. whereas the white-flowered plants were described as *C. intybus* forma *album* Neum. He goes on to note that records of both forms are known from southern Ontario near Ajax (OAC) and from southwestern Quebec (MT).

Literature Cited

Bailey, L. H. 1949. Manual of cultivated plants of North America. The MacMillan Company, New York. 1116 pages.

Budd, A. C. and **K. F. Best.** 1969. Wild plants of the Canadian Prairies. Canadian Department of Agriculture. Queens Printer, Ottawa. 519 pages.

Clark, L. J. 1973. Wildflowers of British Columbia. Gray's Publishing Limited, Sidney, British Columbia.

Frankton, C. 1967. Weeds of Canada. Canada Department of Agriculture, Ottawa, Ontario. 196 pages.

Hitchcock, C. L., A. Cronquest, M. Ownby, and **J. Thompson.** 1955. Vascular plants of the Pacific Northwest. Part 5: Compositae. University of Washington Press, Seattle. 343 pages.

Looman, J., and **K. F. Best.** 1979. Budd's Flora of the Canadian Prairie Provinces. Agriculture Canada Publication 1662. Ministry of Supply and Services, Hull, Quebec. 863 pages.

Moss, E. H. 1959. Flora of Alberta. University of Toronto Press, Toronto. 546 pages.

Munz, P. A. 1959. A California Flora. University of California Press, Berkeley and Los Angeles. 1681 Pages.

Scoggan, H. J. 1979. Flora of Canada Part 4. National Museum of Canada, Ottawa.

Taylor, R. L., and **B. McBryde.** 1977. Vascular plants of British Columbia: a desciptive resource inventory. Technical Bulletin Number 4. The Botanical Garden. University of British Columbia Press, Vancouver. 754 pages.

Polunin, O. 1969. Flowers of Europe: a field guide. Oxford University Press, London. 663 pages.

Received 25 July 1991
Accepted 17 February 1992

The Relation between Premolar Wear and Age in Yellow-bellied Marmots, *Marmota flaviventris*

DIRK VAN VUREN[1] AND CARMEN M. SALSBURY[2]

[1]Department of Wildlife and Fisheries Biology, University of California, Davis, California 95616
[2]Department of Systematics and Ecology, University of Kansas, Lawrence, Kansas 66045

Van Vuren, Dirk, and Carmen M. Salsbury. 1992. The relation between premolar wear and age in Yellow-bellied Marmots, *Marmota flaviventris*. Canadian Field-Naturalist 106(1): 134–136.

We evaluated the utility of the premolar gap technique for estimating age of Yellow-bellied Marmots (*Marmota flaviventris*). Premolar wear increased linearly with age through four years, then stabilized. The technique is unsuitable for estimating ages of marmots older than three years, but shows promise for marmots one through three years old.

Key Words: Yellow-bellied Marmot, *Marmota flaviventris*, age estimation, premolar wear, premolar gap.

Ground-dwelling squirrels have provided fruitful opportunities for research on a variety of topics in population biology (Murie and Michener 1984). Knowledge of the age of individual squirrels often is important, but age can be determined reliably only for individuals first captured and marked as young of the year (Erlien and Tester 1984; King and Murie 1985) or when young enough to be aged by body mass (Armitage et al. 1976; Boag and Murie 1981). Even in studies that are of sufficient duration to include known-age adults, previously unmarked adults may immigrate into the population (Schwartz and Armitage 1980; Sherman and Morton 1984).

Few non-destructive techniques are available for estimating age of ground-dwelling squirrels (Sherman et al. 1985; Hoogland and Hutter 1987; Cox and Franklin 1990; Stockrahm and Seabloom 1990), and generality to other species is known for none. One of these techniques, the premolar gap, has proven useful in estimating the ages of Black-tailed Prairie Dogs (*Cynomys ludovicianus*) (Cox and Franklin 1990). Our objective was to evaluate the generality of the premolar gap technique by describing the relationship between premolar wear and age in a second species of ground-dwelling squirrel, the Yellow-bellied Marmot (*Marmota flaviventris*).

Methods

Yellow-bellied Marmots near Rocky Mountain Biological Laboratory, Gunnison County, Colorado, have been the subjects of a long-term study (Armitage 1991). Each year since 1962, all young of the year in the study area were trapped and permanently marked with numbered ear tags shortly after first emergence from the natal burrow. Thus, the age of most marmots in the study area was known.

During the summer of 1990, we trapped 45 known-age marmots that were one year old or older, chemically restrained them with an injection of ketamine hydrochloride (Frase and Van Vuren 1989), and measured the distance between the paraconid and protoconid cusps of the lower left premolar (Cox and Franklin 1990) using calipers with 0.05 mm precision. Young of the year were excluded from the study because they are easily distinguished from other age classes on the basis of body mass (Armitage et al. 1976).

We grouped marmots into monthly age classes based on the summer active season when tooth wear occurred. Premolar wear presumably results from masticating food; because marmots hibernate from mid-September until early May and greatly reduce their feeding during September (Melcher et al. 1989), almost all mastication occurs May through August. We calculated monthly age classes by summing the active season months (May-August) for each marmot, beginning with May of the yearling summer and ending with the month of capture. Thus, marmots trapped during July of their yearling summer were assigned to monthly age class 3, two-year-olds trapped during May were assigned to monthly age class 5, and so forth. Monthly age classes allowed better resolution of the relationship between tooth wear and the amount of time the teeth were used than did annual age classes.

The relationship between premolar wear and monthly age class of marmots from May at age one year through August at age four years was evaluated with linear regression. We obtained an a posteriori estimate of accuracy by using the empirically derived regression equation to "predict" the annual age class of known-age marmots one to four years old (Sherman et al. 1985). Each annual age class comprises four monthly age classes; thus, prediction was scored as accurate if monthly age class computed from the regression equation fell within two months of the true monthly age class.

Results

The relationship between premolar wear and age was asymptotic; the premolar gap increased with age until marmots were four years old, then stabilized

(Figure 1). Cox and Franklin (1990) likewise reported a decrease in rate of tooth wear in Black-tailed Prairie Dogs at about four years of age.

Regression analysis of premolar wear from May of the yearling summer through August at age four years indicated a significant relationship between wear and age ($r^2 = 0.85$, $F_{1,35} = 205.11$, $P < 0.001$). Males (n=10) and females (n=27) were combined because their separate regression equations did not differ (analysis of covariance, $F_{1,33} = 1.149$, $P = 0.29$). The premolar gap widened at a rate of 0.12 mm per month of above-ground activity.

Annual age class was accurately predicted for 54% of 37 marmots. Extending the criterion for accuracy to ±2.5 months improved prediction success to 78%.

Discussion

The premolar gap technique is unsuitable for estimating the ages of marmots older than three years. The age-related increase in premolar wear, however, does provide a basis for estimating the age of marmots according to four annual age classes: one, two, three, or four and older. The 54% prediction accuracy falls short of the reliability that researchers typically desire, but it is a substantial improvement over classifying first-time captures as age unkown. Moreover, the dramatic increase in accuracy resulting from a modest relaxation of the accuracy criterion suggests that many incorrect predictions were close to being correct. Accuracy of age estimation for marmots might be improved by combining measures of premolar wear with age-specific changes in body mass (Armitage et al. 1976).

We conclude that the premolar gap technique has potential for estimating the ages of Yellow-bellied Marmots. Given the need for such a technique for ground-dwelling squirrels in general, we believe that the approach deserves further consideration.

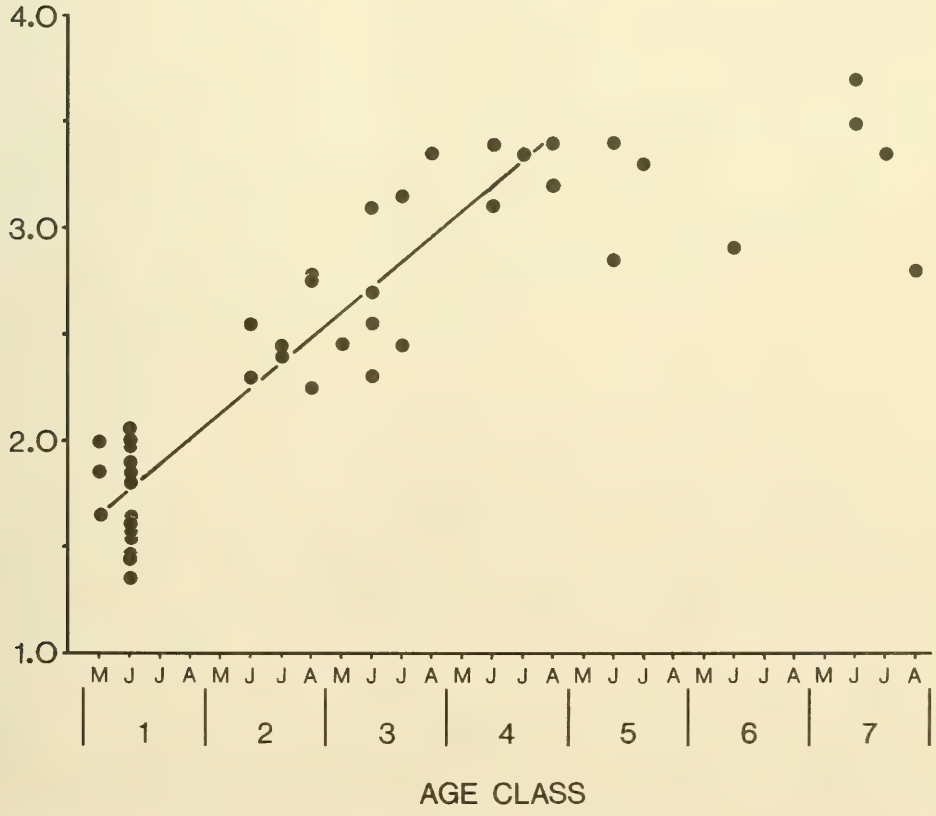


FIGURE 1. Relation between premolar wear and age among Yellow-bellied Marmots in Colorado. Age class is presented in two scales. The upper scale indicates sequential months of above-ground activity (May through August), and the lower scale indicates the grouping of monthly age classes into annual age classes through seven years old. Premolar gap is regressed on monthly age class ($Y = 1.52 + 0.12X$) for marmots one through four years old. See text for further explanation.

Acknowledgments

We thank D. W. Johns and K. B. Armitage for assistance. This study was funded by the University of California at Davis and a National Science Foundation Grant to K. B. Armitage.

Literature Cited

Armitage, K. B. 1991. Social and population dynamics of yellow-bellied marmots: results from long-term research. Annual Review of Ecology and Systematics 22: 379–407.

Armitage, K. B., J. F. Downhower, and **G. E. Svendsen.** 1976. Seasonal changes in weights of marmots. American Midland Naturalist 96: 36–51.

Boag, D. A., and **J. O. Murie.** 1981. Weight in relation to sex, age, and season in Columbian ground squirrels (Sciuridae: Rodentia). Canadian Journal of Zoology 59: 599–1004.

Cox, M. K., and **W. L. Franklin.** 1990. Premolar gap technique for aging live black-tailed prairie dogs. Journal of Wildlife Management 54: 143–146.

Erlien, D. A., and **J. R. Tester.** 1984. Population ecology of sciurids in northwestern Minnesota. Canadian-Field Naturalist 98: 1–6

Frase, B. A., and **D. Van Vuren.** 1989. Techniques for immobilizing and bleeding marmots and woodrats. Journal of Wildlife Diseases 25: 444–445.

Hoogland, J. L., and **J. M. Hutter.** 1987. Using molar attrition to age live prairie dogs. Journal of Wildlife Management 51: 393–394.

King, W. J., and **J. O. Murie.** 1985. Temporal overlap of female kin in Columbian ground squirrels (*Spermophilus columbianus*). Behavioral Ecology and Sociobiology 16: 337–341.

Melcher, J. C., K. B. Armitage, and **W. P. Porter.** 1989. Energy allocation by yellow-bellied marmots. Physiological Zoology 62: 429–448.

Murie, J. O., and **G. R. Michener,** *Editors*. 1984. The biology of ground-dwelling squirrels. University of Nebraska Press, Lincoln. 459 pages.

Schwartz, O. A., and **K. B. Armitage.** 1980. Genetic variation in social mammals: the marmot model. Science 207: 665–667.

Sherman, P. W., and **M. L. Morton.** 1984. Demography of Belding's ground squirrels. Ecology 65: 1617–1628.

Sherman, P. W., M. L. Morton, L. M. Hoopes, J. Bochantin, and **J. M. Watt.** 1985. The use of tail collagen strength to estimate age in Belding's ground squirrels. Journal of Wildlife Management 49: 874–879.

Stockrahm, D. M. B., and **R. W. Seabloom.** 1990. Tooth eruption in black-tailed prairie dogs from North Dakota. Journal of Mammalogy 71: 105–108.

Received 15 April 1991
Accepted 20 February 1992

News and Comment

Notice of the 1993 Annual Business Meeting of The Ottawa Field-Naturalists' Club

The 114th Annual Business Meeting of The Ottawa Field-Naturalists' Club will be held in the auditorium of the Victoria Memorial Museum Building, McLeod and Metcalfe streets, Ottawa on Tuesday 12 January 1993 at 19:30 h.

CONNIE CLARKE

Recording Secretary

Call for Nominations: The Ottawa Field-Naturalists' Club 1992 Awards

Nominations are requested from Ottawa Field-Naturalists' Club members for the following: Honorary Membership, Member of the Year, Service, Conservation, and the Ann Hanes Natural History Award. Descriptions of these awards appeared in *The Canadian Field-Naturalist* 96(3): 367 (1982). With the exception of nominations for Honorary Member, all nominees must be Club members in good standing.

ENID FRANKTON

Chair, Awards Committee, 2297 Fox Crescent, Ottawa, Ontario K2B 7R5

Call for Nominations: The Ottawa Field-Naturalists' Club 1993 Council

Candidates for Council may be nominated by any Ottawa Field Naturalists' Club member. Nominations require the signature of the nominator and a statement of willingness to serve in the position for which nominated by the nominee. Some relevant background information on the nominee should be also provided.

BILL GUMMER

Chairman, Nominating Committee, 2230 Lawn Avenue, Ottawa, Ontario K2B 7B2

Errata: *Canadian Field-Naturalist* 105(4)

Theberge, John B. 1991. Ecological classification, status, and management of the Gray Wolf, *Canis lupus*, in Canada. Canadian Field-Naturalist 105(4): 459–463.

A drafting error was made in Figure 1, page 461 which is corrected in the revision below:

0 400 800 km.
Arctic Ocean
Hudson Bay
Pacific Ocean
Atlantic Ocean
U.S.A.
PREY – BASED ECOTYPES
GEOGRAPHIC– FOREST REGION – BASED ECOTYPES
A – White-tailed Deer - Moose Wolf ↔ Hardwood Boreal Transition Wolf
B – Moose - Caribou Wolf ↔ Boreal Wolf
C – Caribou Wolf ↔ Eastern Tundra Wolf
D – Caribou - Muskox Wolf ↔ Western Tundra Wolf
E – Bison Wolf ↔ Northern Parkland Wolf
F – Elk - Deer - Moose - Caribou Wolf ↔ Northern Rocky Mountain Wolf
G – Mule Deer - Moose Wolf ↔ Mid-Cordillera - Southwest Boreal Wolf
H – Mule Deer - Moose - Caribou Wolf ↔ Northern Alberta and Region Wolf
I – Caribou - Moose - Dall Sheep Wolf ↔ Northwest B.C. - Yukon Wolf
J – Black - tailed Deer Wolf ↔ Vancouver Island Wolf
Wolves Extirpated

FIGURE 1. Wolf Ecotypes in Canada

Minutes of the 113th Annual Business Meeting of The Ottawa Field Naturalists' Club, 11 February 1992

Place and Time: Auditorium, Canadian Museum of Nature, Metcalfe and McLeod Streets, Ottawa, 20:00 hrs
Chairperson: Elizabeth Fox, Acting President
Attendance: Forty-four people attended the meeting

1. Minutes of the Previous Meeting
Enid Frankton, Acting Recording Secretary, read the minutes of the 112th Annual Business Meeting. It was moved by Jack Romanow (2nd Colin Gaskell) that the minutes be approved.

(Motion Carried)

2. Business Arising from the Minutes
(a) Council continues to meet at the Friends of the Farm office at the Arboretum of the Central Experimental Farm. This location has proven to be satisfactory and convenient. Appreciation to Friends of the Farm was expressed.
(b) President Roy John left Ottawa in September 1991 to take up a new position in Halifax, N.S. Fox paid tribute to his generous leadership, and enthusiastic participation in many of the Club's activities and projects.

3. Financial Report
Gillian Marston, Treasurer, provided copies of the Financial Statements for the year ended September 30, 1991. The Financial Statements showed several points of interest. Members' equity, the Club's accumulated surplus of funds, is $178,661, up from $131,657 in 1990. Total Club Activity Expenses were higher mainly due to $1,547.00 contributed to the Wetlands Preservation Group of West Carleton. In CFN operations the excess of income over expenses was $30,917.00 compared to last year's figure of $6,177.00, the result of publishing seven issues of *Canadian Field Naturalist*, and special issues to COSEWIC. It was moved by Gillian Marston (2nd Frank Pope) that the Financial Report be accepted.

(Motion Carried)

4. Nomination of Auditor
It was moved by Frank Pope (2nd Ellaine Dickson) that Janet Gehr continue as auditor of *The Ottawa Field¬Naturalists' Club* for the 1991/92 fiscal year.

(Motion Carried)

5. Report of Council
The following Committee reports for 1991 were read by Elizabeth Fox and Enid Frankton: Awards, Birds, Computer Management, Conservation, Education & Publicity, Excursions & Lectures, Executive, Finance, Fletcher Wildlife Garden, Macoun Field Club, Membership and Publications. A missing line was added to the Finance report. It was moved by Frank Pope (2nd Barbara Campbell) to accept the Report of Council.

(Motion Carried)

6. Report of Nominating Committee
(a) Bill Gummer reported the following slate of officers and members nominated for the 1992 Council:
President: Frank Pope (Executive)*
Vice Presidents: (none nominated)
Recording Secretary: Connie Clark**
Corresponding Secretary: Eileen Evans
Treasurer: Gillian Marston
Council Members: Ron Bedford (Publications)
Barry Bendell (Macoun Field Club)
Fenja Brodo
Steve Blight
Lee Cairnie** (Rep. Education & Publicity)
Martha Camfield
Bill Cody
Francis Cook
Don Cuddy (Rep. Conservation)
Ellaine Dickson**
Enid Frankton (Awards)
Colin Gaskell (Excursions & Lectures)
Bill Gummer
Jeff Harrison (Wild Life Garden)
Michael Murphy** (Computer Management)
Jack Romanow** (Rep. Birds)
Doreen Watler (Membership)
Ken Young (Finance)

* Names of Committee Chairs (or Representatives in three cases) are followed by names of their Committees in parentheses.
** New members of the Council.

Barbara Campbell
Eileen Evans
Bill Gummer

The following are no longer members of Council: Roy John, Elizabeth Fox, Christine Firth, Stewart

MacDonald, Lynda Maltby. Nick Stow acted as recording secretary for much of the year.

The new Council must choose two vice presidents, since no one has come forward at this time. It was moved by Bill Gummer (2nd Barbara Campbell) that the Nominating Committee recommendations for the 1992 Council be approved.
(Motion Carried)

Gummer noted that there are 85 names on 11 committees, and 75 people involved. He also noted that all committees are represented on the Council.

7. New Business
(a) Frank Pope, the new president, took the chair. He thanked the outgoing Council, with special thanks to Elizabeth Fox who has been Acting President.

(b) Bill Gummer paid tribute to the late George McGee, and noted that a tribute to him will appear in *Trail & Landscape*.

(c) Gummer announced that (i) Terms of Reference of Officers and Committees of the Club have been brought up to date and will be available at monthly meetings, and (ii) Constitution and By-Laws are undergoing a complete review. Some articles were badly out of date, and a number of corrections and clarifications have been made. These will be published in the Canadian Field Naturalist before the Annual Business Meeting (1993) for discussion and approval.

(d) Pope explained that the 1992 Annual Business Meeting had to be postponed due to inclement weather. He asked that this Annual Meeting ratify decisions made at the two Council meetings which have been held since then. It was moved by Sheila Thomson (2nd Elizabeth Fox) that decisions made at the two Council meetings now be accepted as the Annual Meeting was postponed.
(Motion Carried)

(e) Pope invited discussion about the procedure of Annual Business Meetings, and several suggestions arose. For instance, the question was raised about the time-consuming reading of all committee reports: one idea advanced is to allow attending members time to read the Council Report at the start of the meeting, and then simply have committee representatives answer questions. Another idea is to feature a critical review of a significant Club activity.

8. Adjournment
At 21:50 it was moved by Barbara Campbell (2nd Ellaine Dickson) that the meeting be adjourned. Members were invited to meet downstairs for refreshments.

COMMITTEE REPORTS FOR 1991

Awards Committee

For the 1990 awards, the Committee based its decisions on only 16 nominations from only 6 Club members; some of these were clear choices, some were "multiple choice", some were only uncertain suggestions. This situation emphasizes the need for action to rekindle interest in Club awards.

The Awards Committee recommended to the Council only three awards for 1990 efforts: Member of the Year — Frances Cook for his strong effort to recover the publication schedule of *The Canadian FieldNaturalist*; Service Award — Robert Lee for his long and active leading role with the Macoun Field Club; Conservation Award — Phil Reilly for his efforts to protect the Constance Creek Wetland. Council accepted these, and also agreed that for the second year in a row there was no obvious and suitable candidate for the Anne Hanes Natural History Award. No nominations for outside awards were received or made.

Enid Frankton will chair the Committee for the 1991 program. Peter Hall and Diana Laubitz are resigning, and new members will be sought.

BILL GUMMER

Birds Committee

In 1991, the Birds Committee devoted most of its energy to maintaining the regular bird-related activities of the Club. These included seasonal summaries of sightings for *Trail & Landscape*, coordinating the Club feeders, reviewing documentation of unusal sightings, and running the spring and fall roundups.

The Christmas bird count was again organized in co-operation with the Outaouais Club, and was successfully held. The OFNC was reasonably well represented at the post-count meeting, but we had hoped for a better turnout of OFNC members.

The increasingly popular Bird Status Line worked well this year, as did the Rare Bird Alert system. A revised list of active participants in the Rare Bird Alert system was put in place to take effect on January 1, 1992.

The Fall Seedathon was again successful this year, and the Committee was supportive of the goals and fund-raising activities of the Baillie Birdathon.

Overall, the Birds Committee was lessactive in 1991 than in some past years. However, it has undergone some important changes and is looking forward to an active and productive year in 1992.

STEVE BLIGHT

Computer Management Committee

The Committee ensures the efficient and controlled use of the computer assets of the Club. It maintains and improves existing systems and increases awareness of how the computer can help other committees with their various needs.

We conducted a survey of Council and all Club committee members to find out how many active Club members already own computers and to determine the need, if any, for communications facilities. The result of the survey indicated that there is no immediate need for a Bulletin Board System.

Committee members have defined the roles and responsibilities of various committees and officers as they relate to the requirements of the existing and proposed new computerized Club Membership Systems. These roles and responsibilities have now been documented, together with such procedures as preparing the *Trail & Landscape* mailing system using labels generated by the Membership System.

The Committee has provided systems maintenance and/or technical support to each of the Club's three computer systems.

MIKE MURPHY

Conservation Committee

The Conservation Committee has commented on behalf of the Club on various conservation and environmental issues, including: Leitrim Wetland, Carp Hills Subdivision, City of Ottawa Official Plan, Gillies' Grove (Arnprior), Carson Grove, and Wychwood (Blueberry Point).

In addition, the Committee has prepared responses to the draft *Wetlands Policy Statement*, and the *Wild Life Policy Discussion Paper* prepared by the *Ministry of Natural Resources*. Members of the Committee have represented the Club to the *Environmental Assessment Board* hearings on *Timber Management in Ontario* as well as the *Sewell Commission on Planning Reform in Ontario*.

MIKE MURPHY

Education & Publicity

This year the Club outings were less frequent than in 1990 due to cancellation of events organized by third parties. The first of the Club's slide shows has been completed and discussions started concerning future projects. Our request for feed-back from the Membership Committee is still awaiting completion. We now have a very strong and willing Committee with each member being extremely competent in their particular job and researching thoroughly before requesting any extra committee items.

RAY KNOWLES

Excursions & Lectures Committee

The Excursions & Lectures Committee organized eight monthly meetings featuring guest speakers who made presentations on various topics of natural history and environmental concern. Arrangements were similarly made for the traditional members' slide night in September. The Committee also worked in conjunction with the Membership Committee to coordinate two successful special events: the annual Club Soiree, and the New Members' Night.

The excursions programme is the other major component of the Committee's responsibilities. A total of thirty-five outings were scheduled within the Ottawa District and another four trips were planned to destinations slightly beyond the local area. In addition, five full-day bus excursions were arranged, although one had to be cancelled due to insufficient registration. The Committee also set up two identification workshops focusing on plants and minerals. The majority of the trips centred on birds, botany or general interest with single trips covering the subjects of amphibians, insects and geology.

In May, the Committee successfully coordinated an extended four¬day birdwatching trip to Point Pelee to witness the spectacle of spring migration.

Unfortunately, with the departure of Roy John for Nova Scotia in September, the Club lost not only its current President but also the presiding Chairman of this Committee. We would like to thank Roy for his valuable contributions to the efficient functioning of this Committee and, on his behalf, thank the various trip leaders and Committee members for their dedicated efforts to ensure the success of this year's programme.

COLIN GASKELL

Executive Committee

The Executive Committee met in March to discuss the 1993 Annual Business Meeting of the Federation of Ontario Naturalists (FON), which will be hosted by the OFNC. Some initial groundwork has been accomplished.

"Habitat" has been chosen as a general theme, with "Habitat: Natural Capital" as a working title. The FON has agreed to this and Steve Blight has agreed to develop and elaborate on these ideas. Eileen Evans has compiled a list of experienced volunteers who worked on the last FON General Meeting which the Club hosted, in 1983, and many of these people have agreed to help again. Various organizational needs and committees were identified, to deal with registration, accommodation, wheelchair facilities and accessibility, social activities, field trips, key speakers, graphics for brochures, displays, programs etc..., and use of the Club's Computer Committee. Some preliminary ideas for key speakers and field trip destinations have been noted.

The appointment of leaders for the various committees and the enlistment of more volunteers to organize the event will be undertaken in the new year.

LIBBY FOX

Finance Committee

The Committee met four times during the year. The annual financial statement and the budget were approved and a recommendation made to the Council to maintain the fee structure unchanged for

another year. A document describing the Club accounts was produced. Issues considered during the year included computer processing costs, insurance for special Club activities, funding opposition to the development of a golf course on Constance Creek, purchase of a slide display screen, review of Club practices pertaining to our status as a charitable organization, and the business and financial activities associated with the Fletcher Wildlife Garden.

Significant financial events during the year included coping with the GST and accepting responsibility for the remaining stock (some 5000 copies) of *Nature and Natural Areas in Canada's Capital*. The Citizen has now recovered the cost of printing this book.

FRANK POPE

Fletcher Wildlife Garden Committee

The seven member Committee was officially recognized as a Committee of the Club at the June 1991 Council meeting.

Much work has been accomplished in the inaugural year. This includes the naming of the garden after James Fletcher, development of Terms of Reference for the Committee and a Memo of Understanding among the Club, *Friends of the Farm* and *Agriculture Canada*. A fulltime coordinator, Elise Stevenson, was hired through an Environmental Youth Corps grant in August 1991. Elise has been provided space, office services and a huge amount of support by *Friends of the Farm*. She has received strong administrative support from Bill Cody.

Procedures were developed by Kim Taylor for flora and fauna inventories and much base line data on what is on the site has already been collected. A nursery has been developed off-site and about 1,000 trees and shrubs planted and maintained by a host of volunteers. They will be replanted on the site in 1992. To date about 30 Virginia Creepers have been planted behind the perimeter fence at the baseball field.

A slide talk on the Wildlife Garden has been developed and presented to half a dozen groups during the year. Most of the slides were provided at no charge by *Friends of the Farm*.

Other activities included a public open house in the spring and in the fall the Committee hosted the Annual Club Picnic, a "Leaf-in" and a birdhouse building workshop led by Jim Wickware with wood procured and pre¬cut by Don Cuddy and donated by the *Ontario Ministry of Natural Resources*.

A dam to control water for the sedge meadow was constructed by *Drummond Construction* and paid for by donation from *Drummond* and *Friends of the Farm*. Two bird feeders were provided on permanent loan from the *National Capital Commission* and installed in the area next to the planned Interpretative Centre. These feeders have been approved as official Club feeders.

JEFF HARRISON

Macoun Field Club Committee

Our Committee is a very active and committed group which cooperates in taking responsibility for leading the field trips and meetings of the Macoun Field Club. The Committee meets every second month to plan its schedule. There are weekly Friday afternoon meetings for Seniors (Grades 9-13). For Juniors (Grades 4-6) and Intermediates (Grades 7-8) there are indoor meetings every second Saturday. Field trips are held on alternate Saturdays.

A couple of special projects were begun in the last year. Juniors and Intermediates have each chosen a tree in the Macoun study area. They will study their trees over the seasons to learn as much as they can about them. This spring, Seniors built a tern nesting platform, which was floated on Shirley's Bay. We succeeded in attracting common terns, but no nests were produced. The Macoun Field Club continues to attract new Junior members, but the number of Senior members is down, and a cause of concern. The Committee welcomes those with time to assist in leading field trips and meetings.

BARRY BENDELL

Membership Committee

The total paid-up membership as of December 1st, 1991 was 1095. Of this number, 121 were new members. Of these, 66 were Individual Memberships and 55 were Family Memberships. Assuming an average

1991 Paid-up Membership in the OFNC

Type	Local	Other	U.S.A	Other	Total
Individual	391 (431)	171 (178)	39 (44)	7 (6)	608 (659)
Family	339 (368)	30 (34)	2 (2)	0 (0)	371 (404)
Sustaining	50 (41)	2 (2)	2 (2)	0 (0)	54 (45)
Life	15 (15)	19 (18)	3 (4)	2 (2)	39 (39)
Honorary	15 (15)	7 (7)	1 (1)	0 (0)	23 (23)
Total	810 (870)	229 (239)	47 (53)	9 (8)	1095 (1170)

of 2 members per Family Membership, the total number of members in the Club is estimated at 1350.

The chart summarizes the membership distribution. The figures for 1990 are in brackets.

There is a total of 111 names on the volunteer list.

The Membership Committee and the Excursions & Lectures Committee again co-hosted the New Members' Night on November 15th. Only 35 new members came out for the evening, but those who did met members of Council and several Honorary members. All enjoyed an evening of information about the Club's activities and history, as well as wine, cheese and other refreshments, in the Salon of the Canadian Museum of Nature.

DOREEN WATLER

Publications Committee

The Publications Committee met three times in 1991 in fulfilling its function of overseeing and advising Council on the Club's publications.

Four issues of *The Canadian Field-Naturalist* (*CFN*) were published in 1991: Volume 104, Issues 3 and 4, and Volume 105, Issues 1 and 2. This almost brings the CFN back to its normal publication schedule, from which it had slipped badly two or three years ago. The editor, Dr. Francis Cook, was named Club Member of the Year for 1990, "... for his extraordinary effort to recover the normal schedule of the CFN". In 1991, the four published issues of the CFN contained 610 pages, 50 articles, 40 notes, 91 book reviews, 265 new titles, 13 COSEWIC reports and 16 pages of News and Comments. We are pleased to note the return of Dr. A. Erskine to full status as Associate Editor following a period of reduced duties. The rest of the panel of Associate Editors remains intact.

There are many subscribers to the CFN who are not members of the Club, largely outside the Ottawa area. This accounts for the wide distribution of the journal and reflects its highly-regarded status. In 1991, the geographical distribution of the subscribers was as follows:

	Institutions	Individuals
Canada		
Nfld	14	3
NS	13	12
PEI	3	3
NB	10	12
Que	26	8
Ont	81	51
Man	15	8
Sask	10	7
Alta	29	39
BC	17	28
NWT	14	4
Yuk	4	5
subtotal	236	180
USA	283	61
Other foreign	54	7
subtotal	337	68
Total	573	248
Grand Total:	821	

Trail & Landscape (T&L), Volume 25, marked Dr. Fenja Brodo's first year as editor, and a very competent job she has done, with help from Suzanne Blain in training and in equipment maintenance. Volume 25 contained 164 pages, 31% of which were connected with birds in some way. This rather high percentage has been a continuing trend since the cessation of publication ot *The Shrike*. Issue 4 contained the 5 Year Index to Volumes 21 to 25, compiled by Joyce Reddoch. Michael Murphy continued to edit The Green Line, a one-page supplement to each issue of *T&L*, that provides timely reports on current environmental issues.

The successful publication of these journals requires the help and efforts of a large number of Club members who serve in a variety of ways. The Committee, and the Club, are indebted to all of them.

RON BEDFORD

The Ottawa Field-Naturalists' Club Financial Statements Year Ended September 30, 1991

Auditor's Report

To the Members of
The Ottawa Field-Naturalist' Club

I have audited the balance sheet of The Ottawa Field-Naturalists' Club as at September 30, 1991, and the statements of operations, members' equity for the year then ended. These financial statements are the responsibility of the organization's management. My responsibility is to express an opinion on these statements based on my audit.

Except as explained in the following paragraph, I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the

accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In common with many non-profit organizations, the Club derives part of its revenue from its members in the form of membership fees and subscriptions, as well as from fund raising activities. These revenues are not readily susceptible to complete audit verification, and accordingly, my verification was limited to accounting for the amounts reflected in the records of the Club.

In my opinion,. except for the effect of the adjustments, if any, which I might have determined to be necessary had I been able to satisfy myself concerning the completeness of the revenue referred to in the preceding paragraph, these financial statements present fairly, in all material respects, the financial position of the organization as at September 30, 1991, and the results of its operations for the year then ended in accordance with generally accepted accounting principles.

JANET GEHR

Ottawa, Ontario
January 14, 1992

The Ottawa Field-Naturalist' Club
BALANCE SHEET
September 30. 1991

	1991	1990
Assets		
CURRENT ASSETS		
Cash	192,493	191,892
Accounts Receivable	10,114	16,874
Interest Receivable	2,019	2,159
Prepaid Expenses	1,394	1,394
	206,020	212,319
FIXED (Note 3)	4,256	5,756
LAND - Alfred Bog	3,348	3,348
	213,624	221,423
Liabilities, Funds and Members' Equity		
CURRENT LIABILITIES		
Account Payable	13,192	69,475
Deferred Income	13,050	10,176
	26,242	79,651
FUNDS (Note 4)	2,721	4,115
LIFE MEMBERSHIPS	6,000	6,000
MEMBERS' EQUITY	178,661	131,657
	213,624	221,423

The Ottawa Field-Naturalist' Club
BALANCE SHEET
September 30. 1991

	1991	1990
EXCESS INCOME (EXPENDITURES)		
The Ottawa Field-Naturalists' Club	12,415	6,024
Canadian Field Naturalist	30,917	6,177
	43,332	12,201
OTHER INCOME		
Donations and Grants	3,672	3,066
Records and Tapes		1,614
	47,004	16,881
MEMBERS' EQUITY, Beginning of Year	131,657	114,776
MEMBERS' EQUITY, End of Year	178,661	131,657

The Ottawa Field-Naturalist' Club
STATEMENT OF OPERATIONS - CFN
Year Ended September 30. 1991

	1991	1990
INCOME		
Membership	10,000	9,500
Subscriptions	24,711	19,938
Sub-Total	34,711	29,438
Reprints	13,570	6,894
Publication charges	38,666	35,972
Back numbers	708	1,552
Interest and exchange	15,386	14,921
Total Income	103,041	88,777
EXPENSES		
Publishing	47,420	60,264
Reprints	4,586	4,619
Circulation	12,902	6,330
Editing	1,002	678
Office assistance	4,200	3,913
Office supplies	663	809
Honoraria	3,000	2,080
Equipment		3,907
GST Rebate	-1,649	
	72,124	82,600
INCOME OVER EXPENSES	30,917	6,177

The Ottawa Field-Naturalist' Club
STATEMENT OF OPERATIONS - OFNC
Year Ended September 30. 1991

	1991	1990
INCOME		
Memberships	17,003	13,603
T&L Subscript. & back issues	647	529
Interest	3,157	3,535
Other sales	5,718	-405
Special Publications	621	656
Total Income	27,146	17,918
EXPENSES		
OPERATIONS EXPENSES		
Affiliation fees	55	30
Computer	1,355	112
Depreciation	1,500	1,918
Membership	1,778	1,560
Office assistant	675	643
Operations	1,951	2,265
OFNC GST Rebate	-690	
Total Operations Expenses	6,624	6,528
CLUB ACTIVITY EXPENSES (Net)		
Awards	29	
Birds	230	96
Conservation	154	98
Education & publicity	198	118
Excursions & lectures	-387	-2,016
Macoun club	846	962
Trail & Landscape	5,490	6,208
Wetlands Preservation Coalition	1,547	0
Total Club Activity Expenses	8,107	5,366
	14,731	11,894
INCOME OVER EXPENSES	12,415	6,024

The Ottawa Field-Naturalist' Club
Notes To The Financial Statement
September 30. 1991

1. *Authority and Activities*

The Ottawa Field-Naturalists' Club is a non-profit organization incorporated under the laws of Ontario (1884). The Ottawa Field-Naturalists' Club promotes the appreciation, preservation and conservation of Canada's natural heritage; encourages investigation and publishes the results of research in all fields of natural history and diffuses information on these fields as widely as possible. It also supports and cooperates with organizations engaged in preserving, maintaining or restoring environments of high quality living things. Membership is open to any person or family, upon application and payment of dues. Payment of the Annual Dues as set out in the By-laws will be a necessary condition of the continuation of Membership.

2. *Significant Accounting Policies*

Membership, subscriptions and donations are recorded as received. All other revenues and expenditures except for inventory are accounted for on the accrual basis. Memberships are allocated to the Canadian Field Naturalist publication on a pre-determined percentage.

Supplies, records, tapes and other items held for resale are expensed when purchased.

Fixed assets are recorded at cost and are depreciated on a straight line basis, for assets acquired prior to 1990. Fixed assets acquired after 1989 are expensed.

Life memberships paid since 1977 are recorded at the fee in effect at that time.

There are 38 life members.

3. *Fixed Assets*

	1991	1990
Cost	$16,748	$16,748
Accumulated Depreciation	12,492	10,992
Net Book Value	4,256	5,756

4. *Funds*

	1991	1990
Baldwin Memorial Fund	$358	$358
Seedathon	1,429	1,423
Anne Haines Memorial Fund	815	815
Alfred Bog	119	1,519
	$2,721	$4,115

Revision of the Constitution and By-Laws of The Ottawa Field-Naturalists' Club

Our Constitution and By-Laws were reprinted in 1986 following several changes. On their appearance, there was an immediate report that some financial statements were obsolete and incorrect. Since then, a number of similar comments on other items have been collected and, as well, suggestions have been made for new aspects. This situation led to a thorough review that has resulted in a rather complete rewriting of both documents.

Effort was made to be more consistent in division between the two documents. For instance, all duties of Officers and Editors are now in the By-Laws. Information on Council's committees has been brought up to date, and responsibilities of all committees are defined in the By-Laws. New legal indemnification coverage has been added to the By-Laws. "Junior Membership", covering Macoun Field Club members, is now formally defined in the Constitution. New financial controls, especially for Special Funds, are also covered in the Constitution.

In final review of the Constitution it became clear that the stated practice for approval of amendments would be an immensely time-consuming procedure — every change, however minor, would require an individual motion, a vote, then publication of both old and new versions in *The Canadian Field-Naturalist*, and at the next Annual Business Meeting individual presentation and voting on each item (Article 23, 1986 edition). Since changes are being made in almost every article, it was recommended that some simplification be attempted to save time, at both Council and Annual Business Meetings. New Article 17 in the revised Constitution permits a faster method of approval when revision of much, or even all, of the document is being proposed. This aspect was thoroughly discussed at the Council meeting on 11 May 1992, leading to full agreement on the final format of new Article 17.

The new By-Laws offer considerable updating and improved wording. Nine new By-Laws are introduced; some of the material comes from the old Constitution (By-Laws 7 and 9), some represent consolidation (By-Laws 8 and 11) and some are quite new (e.g. 16, which is based on legal advice). Council also approved the new By-Laws on 11 May, 1992.

Final agreement on the redrafted documents capped a period of intensive review, during which the Council provided useful comments and suggestions. I also wish to acknowledge the thorough participation of Frank Pope and Steve Blight in the revision discussions. Club members are asked to study the proposed new documents and, if they have questions or comments, to provide them to the Council up to and at the next Annual Business Meeting in January 1993, when the documents will be brought out for approval.

BILL GUMMER

The Ottawa Field-Naturalists' Club Constitution

(May 11, 1992)

Articles of the Constitution

1. Name and Status
2. Objectives
3. Membership
4. Institutions
5. Patrons
6. Club Moneys and Securities
7. Officers
8. The Council
9. Committees of Council
10. Auditor
11. Business Meetings
12. Elections and Appointments
13. Term of Office
14. Quorum
15. Publications of the Club
16. Expulsion from the Club
17. Amendments
18. By-Laws

Article 1. NAME AND STATUS

The official name of the Club shall be THE OTTAWA FIELD-NATURALISTS' CLUB. It is a non-profit organization incorporated under the laws of the Province of Ontario (1884).

All assets and other accretions of the Club shall be used in promoting the Objectives of the Club and in no way shall be used for the purpose of personal financial gain for any of its members. In the event of dissolution of the Club, all remaining assets, after payment of liabilities, shall be distributed to one or more recognized charitable organizations in Canada that promote the understanding and preservation of nature. These organizations shall be selected by the final executive, or by a special committee appointed for the purpose.

Article 2. OBJECTIVES

The objectives of the Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and co-operate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Article 3. MEMBERSHIP

Any person or family shall, upon application and payment of dues, become a member of the Club. Payment of the Annual Dues as set out in the By-Laws will be a necessary condition for the continuance of Membership, excepting Life Members, Honorary Members and Junior Members.

(a) Individual Membership
A person shall be granted an Individual Membership upon payment of the annual fee, the amount of which shall be set out in the By-Laws.

(b) Family Membership
A family shall consist of either a couple without children, or one or both parents and any dependent children up to the age of eighteen. A family shall be granted a Family Membership upon payment of the annual fee, the amount of which shall be set out in the By-Laws.

(c) Sustaining Membership
A person or family shall be granted a Sustaining Membership upon payment of the annual Sustaining Membership fee, the amount of which shall be set out in the By-Laws.

(d) Life Membership
A person shall be granted a Life Membership upon a single payment of a fee, the amount of which shall be set out in the By-Laws.

(e) Honorary Membership
Any person (not necessarily a Club member) who has to a marked degree assisted toward the successful working of the Club, or who has made an outstanding contribution to Canadian natural history may be elected by the Council to Honorary Membership in the Club. The family of an Honorary Member shall be granted the privileges of Family Membership.The number of Honorary Members at any one time shall be limited to the number set out in the By-Laws.

(f) Junior Membership
Members of the Macoun Field Club, an activity of the Club designed to encourage young people to study and appreciate nature, shall be considered as junior members of THE OTTAWA FIELD-NATURALISTS' CLUB. As such, they shall enjoy the privileges of membership, except those described in Article 3(g) below.

(g) Privileges of Membership
Members may participate in all Club activities and are eligible to receive Club periodicals, if desired. Members, excepting dependent children and Junior Members, may hold office and may vote at the Annual Business Meeting and at a Special Business Meeting.

Article 4. INSTITUTIONS

Institutions cannot hold Membership in the Club but may subscribe to the publications of the Club, and make donations to the Club.

Article 5. PATRONS

The Council shall have power to elect a Patron or Patrons, not to exceed two in number at any time, given their consent.

Article 6. CLUB MONEYS AND SECURITIES

Moneys and securities shall be deposited in the name of the Club. The Club shall exercise prudent management of investments and cash reserves to meet operating expenses yet earn maximum income through secure investment.

Special Funds, e.g. Memorial Funds, may be set up, with a two-thirds majority approval of the Council at a scheduled meeting. The specific purpose of each Special Fund must be clearly defined. If a Special Fund is to bear interest, this must also be clearly stated. Interest accrued by these Special Funds shall be identified. Special funds shall be reviewed and approved annually by the Council.

Article 7. OFFICERS

Officers of the Club shall be a President, two Vice-Presidents, a Recording Secretary, a Corresponding Secretary, and a Treasurer. Duties of officers are set out in the By-Laws.

Article 8. THE COUNCIL

The Council shall consist of the officers of the Club and up to eighteen additional members, all members of the Club. The Council shall meet regularly each month (except July and August), and otherwise at the call of the President or any two other members of the Council; it shall manage matters affecting the welfare and activities of the Club; it shall have control of the moneys of the Club; it shall present a report on the year's work at the Annual Business Meeting. This report shall be published in *The Canadian Field-Naturalist.*

Article 9. COMMITTEES OF COUNCIL

The Council shall appoint committees for specific activities. The committees may be considered as "standing", i.e. expected to exist for a continued and indefinite time period,or "ad hoc", i.e. aimed at a project of a definite time extent.

Committees shall be responsible for carrying out the assigned activities, within the allocated budget and as approved by the Council. Each Standing Committee shall consist of at least six members appointed by the Council. The chairs, or at least one member of each committee, shall be a member of the Council.

Standing committees are: Awards, Birds, Computer Management, Conservation, Education & Publicity, Excursions & Lectures, Executive, Finance, Macoun Field Club, Membership, and Publications. The Nominating Committee and the Fletcher Wildlife Garden Committee are considered to be *ad hoc* committees.

Responsibilities of standing and *ad hoc* committees are summarized in the By-Laws. Special membership requirements and responsibilities are also set out in the By-Laws.

Article 10. AUDITOR

An Auditor shall be elected by open vote at the Annual Business Meeting. The Auditor shall examine the Treasurer's accounts and certify as to their correctness, and record an opinion as to whether the statements present fairly the financial position of the Club at year end, and whether the results are presented in accordance with generally accepted accounting principles.

Article 11. BUSINESS MEETINGS

The Annual Business Meeting of the Club shall normally be held in January.

A Special Business Meeting of the Club shall be called by the Recording Secretary on the request of the Council, or of twenty voting members of the Club. The notice of such a meeting shall specify the nature of the business to be transacted. At the meeting, no business other than that for which the meeting was called shall be transacted except by unanimous decision of all Club members present.

Article 12. ELECTIONS AND APPOINTMENTS

The officers of the Club and other members of the Council shall be elected annually at the Annual Business Meeting. The nomination of sufficient persons for election to the various offices and membership of the Council shall be the responsibility of the Nominating Committee, which shall act in the manner prescribed in the By-Laws.

The Council shall, at the earliest possible date, appoint chairs and members of Standing and *ad hoc* committees, and Editors and Business Managers, as required, for club publications.

The Council shall have the power to accept any resignation and to appoint any member of the Club to fill any vacancy for the remainder of the original term of office.

Article 13. TERM OF OFFICE

All members of the Council, auditors, and committee members elected or appointed pursuant to Articles 8, 10 and 12 shall commence their duties at the close of the meeting at which they are elected or appointed, and shall serve until the end of the next Annual Business Meeting or an earlier resignation date. Appointments of Editors and Business Managers of Club publications pursuant to Article 12 shall be for specified terms not exceeding three years, and shall be renewable.

Article 14. QUORUM

Twenty members shall constitute a Quorum at the Annual Business Meeting or at any Special Business Meeting of the Club, and seven members shall constitute a Quorum of the Council.

Article 15. PUBLICATIONS OF THE CLUB

(a) The Club shall have a Publication Policy that shall be kept up to date, and altered only with the approval of the Council. The policy shall state the purposes of publications, and advise and recommend on their future courses. The policy shall cover periodicals and any special publications that may be proposed.
(b) The Club shall publish *The Canadian Field-Naturalist*, a scientific journal. This is the official journal of the Club.
(c) The Club shall publish *Trail & Landscape,* a journal for local field observations and for news.
(d) The Club may publish special publications as approved by the Council.

Article 16. EXPULSION FROM THE CLUB

Any individual may be expelled from the Club for conduct or activities prejudicial to the objectives and the well-being of the Club. The procedure shall be set out in the By-Laws.

Article 17. AMENDMENTS

(a) There shall be two procedures for amending the Constitution, as given in sections (b) and (c) of the Article. The normal procedure to be used shall be that

set out in section (b), unless because of a major revision the Council votes, by a two-thirds majority, to use the procedure set out in section(c). In either case, written notice of proposed amendments shall be sent to the Editor of *The Canadian Field- Naturalist* prior to June 1 so that they may be published at least one month before they are to be presented at the Annual Business Meeting the following January.

(b) The normal procedure shall be that each proposed amendment to the Constitution shall deal with only one article, and shall be moved by one member of the Council and seconded by another. At the Annual Business Meeting, each motion for amendment shall be moved, seconded and discussed separately; each amending motion may itself be amended and carried by a two-thirds majority of the members present.

(c) In the case of major revision to the Constitution, a proposed amendment may comprise a group of new or revised articles. The proposed amendment shall be moved by one member and seconded by another. At the Annual Business Meeting, the motion for amendment shall be moved, seconded and discussed in its entirety; each amending motion may itself be amended and carried by a two-thirds majority of the members present.

Article 18. BY-LAWS

The Council may make By-Laws that are consistent with the provisions of the Articles of this Constitution. The By-Laws and any amendments thereto shall be published in *The Canadian Field-Naturalist.*

BILL GUMMER

The Ottawa Field-Naturalists' Club By-Laws

(May 11, 1992)

1. Alternate Name
2. Fiscal Year
3. Disbursements of Club Moneys
4. Membership Dues and Subscription Fees
5. Schedule of Dues and Fees
6. Honorary Members
7. Duties of Club Officers
8. Standing Committee responsibilities to the Council
9. Ad hoc Committee responsibilities to the Council
10. Operating Terms of Reference
11. Committee membership requirements and limitations
12. General Meetings
13. Order and Conduct of Business Meetings
14. Meeting Notification
15. Annual Reports
16. Indemnification clause
17. Duties of Editors
18. Business Managers
19. Treasurer's Assistant
20. Remuneration and Honoraria
21. Expulsion from the Club
22. Amendments

1. ALTERNATE NAME

THE OTTAWA FIELD-NATURALISTS' CLUB shall also be known by the style name, Ottawa Field Naturalists.

2. FISCAL YEAR

The fiscal year of the Club shall extend from the beginning of October to the end of the following September.

3. DISBURSEMENTS OF CLUB MONEYS

Disbursement of Club moneys shall be made by the Treasurer on receipt of properly rendered accounts verified by the Chair of the committee involved, or by a Business Manager, or as specified by the Council. The signing authorities shall be the President, the Treasurer, and the Business Manager of *The Canadian Field-Naturalist*, and disbursements shall be made only by cheque bearing the signature of one of these authorities.

4. MEMBERSHIP DUES AND SUBSCRIPTION FEES

The schedule of dues and fees shall be approved by the Council each year, upon recommendation of the Finance Committee.

5. SCHEDULE OF DUES AND FEES

The current schedule is:

Memberships	Individual	$23
	Family	$25
	Sustaining	$50
	Life	$500
Subscriptions		
The Canadian Field¬Naturalist		
Individual		$23
Libraries and Institutions		$38
Trail & Landscape		
Libraries and Institutions		$23

6. HONORARY MEMBERS

The number of Honorary Members at any one time shall be limited to 25. A change in this limit shall require approval of the Council.

7. DUTIES OF CLUB OFFICERS

(a) The President

The President shall represent the Club and the Council at all times; shall arrange, and preside at, meetings of the Council, Executive Committee, and Business Meetings; and is to be considered an *ex-officio* member of any standing or *ad hoc* committee.

(b) The Vice-Presidents

In the absence of, or at the request of the President, either Vice-President shall act in the President's stead. The membership of each active committee shall contain at least one of the Vice-Presidents to act as liaison between the Council and its committees.

(c) The Recording Secretary

The Recording Secretary shall record minutes of the proceedings of the Council, the Annual Business Meeting, and Special Business Meetings; shall be the custodian of the Constitution and the By-laws and of the official records of the Club; shall compile the Annual Report of the Council and shall make it available to the general membership at the Annual Business Meeting; shall arrange notices of these meetings.

(d) The Corresponding Secretary

The Corresponding Secretary shall deal with the correspondence as directed by the President and the Council.

(e) The Treasurer

The Treasurer shall be charged with the collection and custody of the moneys of the Club and shall keep a systematic account thereof, which shall at any time be open to the inspection of the Council or of the Auditor; shall make disbursements as authorized by the By-laws or by decision of the Council; shall prepare annual financial statements for the membership; shall submit to the Council an annual budget for the Club, and shall submit to Finance Committee recommendations concerning changes to fees, subscriptions, and other charges or costs.

8. STANDING COMMITTEE RESPONSIBILITIES TO THE COUNCIL

(a) Awards Committee shall be responsible for nominating members for Club awards or outside awards; and also for nominating Honorary Members. Nominations will be recommended to the Council.

(b) Birds Committee shall be responsible for coordinating bird-related activities within the Club, and encouraging interest in birds within and outside the Club.

(c) Computer Management Committee shall be responsible for advising the Council on the proper use of and planning for the Club's computer equipment.

(d) Conservation Committee shall be responsible for the conservation activities of the Club, and for keeping members informed of environmental issues.

(e) Education & Publicity Committee shall be responsible for providing information on the Club to the public, and for assisting other organizations with speakers and leaders when possible.

(f) Excursions & Lectures Committee shall be responsible for the Club's annual program of trips and lectures.

(g) Executive Committee shall be responsible for dealing with emergency matters and for providing direction in difficult or sensitive areas, as well as ensuring ongoing operation of the Club.

(h) Finance Committee shall be responsible for monitoring the financial activities of the Club, and for advising the Council on financial matters.

(i) Macoun Field Club Committee shall be responsible for the operation of the Macoun Field Club, including lectures, field trips and studies.

(j) Membership Committee shall be responsible for processing membership applications (after fee payments have been recorded in Treasurer's records), maintaining accurate records of same, and providing useful liaison between the Council and general membership.

(k) Publications Committee shall be responsible for all matters pertaining to existing and proposed publications of the Club, and for nominating Editors and Business Managers for the publications. It shall act as liaison between the Council and the Editors.

9. AD HOC COMMITTEE RESPONSIBILITIES TO THE COUNCIL

(a) Nominating Committee, to be appointed by the Council early in each year, shall be responsible for presenting to the Annual Business Meeting a slate of candidates for election as officers and as members of the Council. Club periodicals shall carry a notice of nomination date and requirements, requesting that all nominations be in writing and be accompanied by statements confirming willingness of nominees to serve. The committee shall also identify vacancies in committee chair positions, and prepare a list of committees and members for approval by the Council at its first meeting of the new calendar year.

(b) Fletcher Wildlife Garden Committee is to develop the site in the Central Experimental Farm, to carry out inventories of flora and fauna, and to plan and arrange projects in the context of a long-term management plan. The committee will work closely with Agriculture Canada and The Friends of the Farm, in accordance with the tripartite Memorandum of Understanding.

10. OPERATING TERMS OF REFERENCE

The duties and responsibilities of Club officers, appointed officials, and all committees shall be written out and maintained in a "Terms of Reference"

book. They shall be updated as necessary, under biennial review. This book establishes common committee responsibilities as well as the specific justification for individual committees.

11. COMMITEE MEMBERSHIP REQUIREMENTS AND LIMITATIONS

(a) Members of all active committees must be Club members in good standing, with two exceptions:

(i) The Macoun Field Club has been co-sponsored since its formation in 1946, by the Canadian Museum of Nature (formerly the National Museum of Natural Sciences), and for this reason the Macoun Field Club Committee should endeavour to include representation from the Museum. The representative(s) need not be Club members.

(ii) Birds Committee (and subcommittees thereof) may include representatives of "Le club des ornithologues de Hull", who need not be members of our Club. Such representatives shall not vote on matters involving Club moneys.

(b) Executive Committee shall include all officers of the Club, with the President as the Chair. The immediate Past-President, if remaining on the Council, shall also be considered a member of the Committee.

(c) The Treasurer, and the Business Manager of *The Canadian Field-Naturalist*, shall be members of the Finance Committee. Business Managers of any other publications or special projects may attend committee meetings and will be kept informed by receiving minutes of meetings.

(d) Publications Committee shall involve Editors and Business Managers, including those of any special projects underway.

(e) All active committees shall include at least one of the Vicepresidents for useful liaison and advice purposes.

(f) Standing Committee chairs shall have the power to add to their committees but Council shall give formal approval to additional members.

(g) The Nominating Committee shall have three members, including at least one member of the Council. The President shall not be a member, nor any Club officer the chair of the Committee.

12. GENERAL MEETINGS

The Club shall hold at least one general meeting each year at which Club affairs shall be discussed. One such meeting, the Annual Business Meeting, shall be for the purpose of reviewing and reporting actions of the past year, electing officers and Council members for the new year, and conducting such other business as may arise.

13. ORDER AND CONDUCT OF BUSINESS MEETINGS

The order of business at the Annual General Meeting and at meetings of the Council shall be:

1. Minutes of the previous meeting
2. Business arising out of the minutes
3. Communications
4. Treasurer's report
5. Reports of Committees
6. New business

The order of business may be changed by a unanimous vote of members present at meetings. All meetings shall be conducted according to the Constitution, By-laws, special Club rules, and normal parliamentary procedure. In all cases where differences of opinion arise, Bourinot's Rules of Parliamentary Procedure shall be followed. Voting by proxy will not be permitted at meetings of the Council or at Business Meetings.

14. MEETING NOTIFICATION

Notice of the Annual Business Meeting and other special meetings shall be published in Club periodicals. Special Council meeting notices shall be arranged by the Recording Secretary. Failure of a member to receive notification of a meeting will not invalidate any action taken at that meeting.

15. ANNUAL REPORTS

(a) All committees shall submit an annual report on the year's program, at the latest by the December meeting of the Council. Annual committee reports require approval from the Council before being accepted for the overall Annual Report of the Club.

(b) There shall be an overall Annual Report of the Club at the end of the calendar year. It shall include minutes of the previous Annual Business Meeting, accounts of activities of each committee, and the audited financial statement of the Club. This report shall be presented at the Annual Business Meeting and shall be published in *The Canadian Field-Naturalist.*

16. INDEMNIFICATION CLAUSE

Every Councillor of the Club, and his/her heirs, executors and administrators, and estate and effects, respectively, may, with the consent of the Club, given at any meeting of the members, from time to time and at all times, be indemnified and saved harmless out of the funds of the Club, from and against,

(a) all costs, charges and expenses whatever that such councillor sustains or incurs in or about any action, suit or proceeding that is brought, commenced or prosecuted against him/her, for or in respect of any act, deed, matter or thing whatever, made, done or permitted by him/her, in or about the execution of the duties of his/her office, and

(b) all other costs, charges and expenses that he/she sustains, or incurs, in or about or in relation to the affairs thereof, except such costs, charges or expenses as are occasioned by his/her own wilful neglect or default.

17. DUTIES OF EDITORS

The Editors of Club publications shall be appointed by the Council. They shall be guided by the Publication Policy concerning editorial policy, content, and preparation of the publications, and shall keep the Publications Committee informed regarding their publications. The Associate Editor(s) of each publication shall assist the Editor.

18. BUSINESS MANAGERS

A Business Manager for *The Canadian Field-Naturalist* shall be appointed by the Council. In addition, the Council may appoint a Business Manager for any other publication or for the Club itself. The duties of the Business Managers shall be specified by the Council.

19. TREASURER'S ASSISTANT

The Council may appoint a Treasurer's Assistant who shall be responsible solely to the Treasurer. Duties will be defined by the Treasurer in consultation with the Business Manager(s), Executive Committee, and appropriate committee chairs.

20. REMUNERATION AND HONORARIA

(a) No remuneration shall be paid to members of the Council or to Club officers in respect of their duties as members of the Council or as officers.

(b) The Treasurer's Assistant will be paid a stipend that will be kept under review by the Finance Committee, and modified as required by the work load.

(c) Honoraria will be paid to Editors and Business Managers of Club publications. The amounts will be recommended by appropriate Committees and approved by the Council.

21. EXPULSION FROM THE CLUB

Any individual(s) may be expelled from the Club for conduct or actions prejudicial to the objectives and the well-being of the Club, by a two-thirds majority vote of the elected Council at a scheduled meeting. The individual(s) will be given the opportunity to present a defense before the Council, prior to the recording of the vote.

22. AMENDMENTS

An amendment to these By-laws may be adopted at any meeting of the Council, by a two-thirds majority of the members present, due notice embodying a copy of the proposed amendment having been given at a previous meeting of the Council. Any such amendment shall be published in *The Canadian Field¬Naturalist.*

Book Reviews

ZOOLOGY

Birds of the Canadian Rockies

By George W. Scotter, Tom J. Ulrich, and Edgar T. Jones. 1990. Western Producer Prairie Books, Saskatoon. xvi + 170 pp., illus. $22.95.

Although billed on the back cover as a field guide, this book is really an introduction to birds of regular occurrence in the Canadian portion of the Rocky Mountains. It is not the comprehensive regional work implied by the title, covering 211 of the approximately 350 species that have been reported to occur there, and detailing none in depth. The book starts with three good maps of the region, followed by a brief introduction on birdwatching, the geophysical features of the region, and bird identification. The bulk of the volume consists of one-paragraph accounts of species illustrated on the opposite page. One to three colour photographs cover each species, with three to four illustrations per photo page and one to three species per text page. A glossary of terms, diagrams of the parts of birds, checklist keyed to various regional parks, selected references, and indices of English and scientific names conclude the book. The taxonomy is current to 1985, and does not incorporate the separation of the Western Flycatcher and Water Pipit into two species each.

The text is lively and mostly written well, although there are several grammatical faults (split infinitives, misplaced onlys, preposition at the end of a sentence, and tense changes in mid-sentence) of a minor nature. Anthropomorphisms also creep in. For example, it is unlikely that Black Swifts consciously delay breeding so that hatching corresponds with the emergence of flying ants. Emphasis is on identification features, but numerous other interesting tid-bits are included.

Seasoned naturalists will learn little that is new, but the text should help sustain the interest of beginners. I found no outright errors of fact, and typographical errors are few. *Totanus flavipes* is misspelled *flavipe* in the text, but is correct in the checklist, while Steller's Jay is spelled correctly in text, but appears as Stellar's in the checklist. Scotter makes liberal use of behavioural and habitat clues to identification, features that will often help the beginner to look up the correct species in a true field guide.

When I first started birdwatching, I was perplexed by Savannah Sparrows with "stick-pins" (breast spots), a feature the guides denied them. Gradually, guides have begun to mention that these sparrows do sometimes sport such spots, but this is the first book I recall that claims Savannah Sparrows generally have them. This statement is true for some areas, but not all populations.

Most of the identification tips are accurate, but some may be slightly misleading. For example, nobody doubts that Rough-legged Hawks hover more frequently than other *Buteos*, but Swainson's do fairly often, and Red-tailed Hawks occasionally. The size difference between the yellowlegs species is obvious to seasoned observers, but size can confuse beginners unless the species are seen together. Some other features are mentioned under one species, but not the other to which it is compared (e.g., the relative head size and "cap" of Cooper's Hawk compared with Sharp-shinned), and some very useful features omitted (e.g., head/face profiles of swans). Other errors are restricted to minor technicalities. For example, juncos aren't just sparrow-sized and sparrow-shaped, they *are* sparrows (Emberizids), the "call" described for the Chipping Sparrow is its song, and although Black Terns are less piscivorous than *Sterna* terns, they catch more fish than indicated. Culture watchers will be disappointed to see U.S. spelling throughout the text.

In light of recent evidence that specimens previously believed to be Arctic Loons in British Columbia were in fact Pacific Loons (R. W. Campbell et al. 1990. *The birds of British Columbia.* Volume 1. Royal British Columbia Museum, Victoria), the Arctic Loon record on the checklist for Yoho National Park bears further evaluation.

In short, this book is a nice introduction to the birds of a major part of Canada. As a showcase of many outstanding photographs, it should make a pleasing gift to serious naturalists likely to spend their own money elsewhere and to aspiring naturalists who could benefit from such an introductory text.

MARTIN K. MCNICHOLL

218 First Avenue, Toronto, Ontario M4M lX4

Anatomy of a Controversy: A Question of a "Language" Among Bees

By A. M. Wenner and P. H. Wells. 1990. Columbia University Press, New York. xiv + 399 pp., illus. U.S. $63.50.

My review copy having its cover bound upside down unfortunately proves an accurate omen of further difficulties. Controversies are as frequent in the study of animal behaviour as elsewhere in science: witness those concerning helping behaviour, pigeon orientation, cognitive ethology, and ape language. Wenner and Wells have long maintained that there is no empirical support for Karl von Frisch's famous and accepted account of bee dances, that their research demonstrating the importance of odour cues in guiding these animals has been deliberately ignored, and that an obstinate and benighted scientific establishment perpetuates this travesty. The resulting lament is a melange of history and philosophy of science, presentation of their own results, and criticism of the experiments of others.

The authors begin with a brief background to the controversy, the alleged aversion of scientists to controversy, and a philosophic and historical perspective. The historical coverage includes everything on bees from Aristotle through Maeterlinck to contemporary investigators. Viewing science as a process occurring in a social context, Wenner and Wells contrast science as it is touted to take place versus its actual course, "realistic" approaches (including Carnap, Popper, and von Frisch) versus "relativistic" ones (including Kuhn and the authors), and attempts of verification versus those of strong inference. Turning to the bees, Wenner and Wells review early work, argue that von Frisch had predecessors and changed his views over the years (this is bad?), and contrast odour and dance interpretations of foraging. Discussion of observed "anomalies" involving conditioning, sounds, behavioural rhythms, and searching patterns leads to a consideration of experiments with multiple controls and more elaborate designs, and a formulation of the odour explanation. In the final chapters, all of this research is examined in a sociological context: the complaints of unfair treatment, affirmations of consequences, and salvaging von Frisch's discredited account by a close-knit scientific network rise in shrillness as they fall in credibility. The book concludes with nearly a hundred pages of "Excursuses" on history, philosophy, accounts of rejected manuscripts, and methodological and empirical topics.

This is a book neither for neophytes seeking an introduction to bee foraging nor for advanced students hoping for a clear description of the issues. Wenner considered the situation in 1973 as "now very complex" and, as one of the reviewers quoted in the present volume aptly puts it, the arguments have now become labyrinthine. More like a court transcript than a scientific adventure, the text is sometimes fascinating but often wearying. The complaints of the authors, who doth protest too much, are strained to the point of paranoia. Their original interest in bee dances has been replaced, as they admit, by one in epistemology and the reaction of biologists to their research. There is an interweaving of science and philosophy, not all of which is clearly relevant to the issues at hand, amid mud slinging, small lumps at James Gould who has suffered from "youthful exuberance" and larger pieces for Nobel Laureate von Frisch who is accused of discounting the importance of odour, selecting his data, withholding important experimental details, and attempting to verify, rather than falsify, hypotheses. The criticisms of the research and attitudes of other individuals in the field are far from cogent. The course of other controversies in the study of animal behaviour makes it fantastic to propose that involving bee dances is some sort of cover up. To assert that von Frisch's accounts "fit in well with a growing romanticism in the incipient fields of sociology and ethology" is a contradictory interpretation which passeth human understanding. This book is the most recent in a long string of similar protests. During a 1973 presentation (published the next year in "Nonverbal Communication") which I attended, Wenner was asked what he thought researchers were observing when they looked at bee dances. "Artifacts" he replied to a disbelieving audience. A similar audience today should be no more sympathetic.

PATRICK W. COLGAN

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Prairiewater: Watchable Wildlife at Beaverhills Lake, Alberta

By Dick Dekker. 1991. BST Publications, 3819-112A Street, Edmonton, Alberta T6J 1K4. 144 pp., illus. $19.95.

Beaverhills Lake, a Ramsar designated wild wetlands site, located an hour's drive east of Edmonton, is one of the best birding sites in Canada. For those wanting background and up to date information on a top birding site this is the book to obtain. It is outstanding in the provision of information on wildlife here. As Jim Butler notes in the introduction to the book, Dekker has roamed the shores as Henry David Thoreau roamed Walden Pond. Dick, with the eyes

of a modern ethologist, makes rich and astute observations of bird behaviour throughout. In preparation of this book he has covered an estimated 14 000 km of foot travel on 1400 days over nearly three decades. These visits have produced numerous details on predator/prey interactions and hunting techniques of both birds and mammals, many documented in delightful detail.

The book, including a good map, provides a focused look at the birds on and around the lake together with habitats, plants, mammals, fishes, amphibians and reptiles. The text begins with a look at the geological features shaping the landscape, earlier and present climates, and a brief review of the aboriginal peoples who came to live here plus the early fur traders and settlers that followed.

As a good wildlife book should do, it begins with a discussion of the resource, the water and life in and around the lake including different water levels throughout recorded history and impacts of this changing shoreline.

This section is followed by birding by the seasons beginning with the arrival of Horned Larks and Snow Buntings in the late winter, followed by mated pairs of Canada Geese, then the large flocks of smaller Canada Geese, and so on. He describes the hordes of White-fronted Geese followed by Snow Geese that come to fatten up for several weeks each spring before heading to Arctic nesting grounds in late May. Masses of Sandhill Cranes come here too. Then come the waves of shorebirds for which the lake shore is so noted. These begin with Yellow Legs, Godwits, Dowitches, and Pectoral Sandpipers in late April and early May and end in early June as the last stragglers go north. Local breeding shorebirds are described and where to find both these and the migrants. He goes on to discuss the returning shorebirds that begin coming back in mid July.

No book on Beaverhills Lake would be complete without a description of the predators that hunt the numerous water birds and Dekker does a good job here too. He has specialized in studying Peregrine Falcons at this site and gives several personal observation accounts of both successful and unsuccessful hunts by this bird of kings. Owls and their impact on bird colonies are also included. His discussion of Short-eared Owls is a delight to read. Dekker includes a good section on birds of the uplands around Beaverhills including when different species arrive and which stay to nest. The section on rarities includes a good description of the first recorded successful nesting of Black-necked Stilts in Canada.

The section on mammals is not as complete as on birds but still meets the needs of visiting naturalists. All of the larger mammals to be found are discussed at some length.

The book closes with checklists of birds, fish, amphibians, reptiles, trees, shrubs, and flowers. A list of references for further reading is a help for those wanting more information.

In summary any naturalist, particularly those keen on birds who visit western Canada should add this book to their library.

J. CAM FINLAY

61-East Whitecroft, 52313 Range Road 232, Sherwood Park, Alberta T8B 1BY

Freshwater Macroinvertebrates of Northeastern North America

By Barbara L. Peckarsky, Pierre R. Fraissinet, Marjory A. Penton, and Don J. Conklin, Jr. 1990. Cornell University Press, Ithaca, New York. 442 pp., illus. Cloth U.S. $57.50; paper U.S. $26.50

This book treats aquatic insects, collembolans, crustaceans, mites, molluscs, and leeches and other oligochaetes. In addition to the authors, several others contributed chapters to the book: Robert W. Bode (Chironomidae), Bruce P. Smith (Hydrachnidia), David Strayer (Mollusca and Oligochaeta), and Donald J. Klemm (Hirudinea). Coverage is restricted to the northeastern North America, including the New England states and the eastern Canadian provinces. The first chapter is a short introduction, followed in Chapter 2 by an ordinal treatment of the orders of aquatic insects and collembola. The remaining seventeen chapters are taxonomic treatments of an order or class of aquatic (or semi-aquatic) invertebrate. Each begins with a very brief summary of the classification, life history, habitat, feeding, respiration, collection and preservation techniques, a discussion of general characters of taxonomic value, a list of references providing more detailed information, and a checklist of the taxa treated in the keys. Most major taxonomic groups are illustrated with one or more labelled drawings of a representative taxon. The keys, which were developed over a period of years as handouts in aquatic entomology classes, treat the larval stages of insects, except for the Hemiptera, and include the adults of those beetles that are aquatic as adults. The keys do not treat aquatic pupae or terrestrial adults. Among the insect orders and the aquatic mites, the treatment is to the genus level. The microcrustaceans (copepods, cladocerans, and others) are keyed only to order, while groups of larger crustaceans are treated at generic or species level. Molluscs other than Sphaeriidae are keyed to species (sphaeriids to genus), and worms and leeches are

keyed to species. Within the keys, family names are presented in bold face to facilitate keying by the more experienced users. Each chapter is followed by a list of references on the systematics and biology of the group in question.

The book is easy to use, and the keys seem to be robust and complete. I used the keys successfully to identify specimens from outside the Northeast. Presumably, eventually there will be taxa found in the Northeast that are not included in the keys, especially among the more poorly known or difficult taxa, but this is not likely to be a problem any time soon.

Many of the illustrations either are original with this work, or are reasonably good modifications of illustrations from the work of others. It is nice to see new illustrations rather than another re-publication of the same figures that everyone has published for the last 50 years.

Freshwater Macroinvertebrates will prove to be a valuable key for students in aquatic entomology classes and for professional consultants working in the region who need a comprehensive general treatment of the fauna. The main drawback of the book is the near complete absence of biological information on the organisms. This restricts its use to identification of the regional fauna, leaving students needing a more comprehensive resource for additional information. However, I suspect aquatic entomology students will not mind, as long as they are not required to purchase another text to fill the gap. Those who are interested in pursuing further information will probably want to buy additional reference works, anyway. Consultants will no doubt welcome the restricted geographic coverage because it will reduce the time spent keying and will decrease the likelihood of making mistakes. For both groups, then, I recommend they get a copy and put it beside their microscopes. It's likely to become a well used reference within a short time.

CHARLES R. PARKER

Uplands Field Research Laboratory, Great Smoky Mountains National Park, Gatlinburg, Tennessee 37736

Neotropical Rainforest Mammals: A Field Guide

By Louise H. Emmons. 1990. The University of Chicago Press, Chicago. xiv + 281 pp., illus. Cloth U.S. $45.00, paper U.S. $19.95.

This book is the first attempt at synthesizing biological knowledge into a field guide format for mammals that live in the Neotropical lowland rainforest, an area defined as Central and South American rainforest below 1000 m in elevation. Covering an ecological region is a different approach because usually geographic regions are used. The objective is to present information in a standardized format within a single reference for both the naturalist and scientist. This provides for a comparison of closely related mammals and identifies species that require further study.

Contents are presented systematically with species or genus accounts with general descriptions for higher levels of classification such as family and order. Most accounts are for individual species, however, due to varying degrees of knowledge of certain groups of small mammals some are left to the generic level because much research is still needed to fully comprehend the subtleties of evolution and ecological distinctions. A brief introduction outlines the sections and format used within each account.

Accounts are prominently identified in bold type with common English names followed by scientific names and a cross reference to illustrations and distribution maps. Sections entitled "identification", "variation", and "similar species" give traditional body measurements, description with diagnostic features in bold, slight differences observed over its range, and distinguishing characteristics that will hopefully allow for proper identification in the field. "Sounds" which may be the only evidence of occurrence, "natural history", and "geographic range" elaborate on any noises emitted, social behaviour, foods eaten, habitat, distribution, and elevation. The remaining topics are "status", "local names", and "references" which explain economic value of the species in terms of hunting for meat or fur, abundance throughout its range, endangered species designation if any, commonly used regional names, and literature sources for more in depth detail on current research.

Six appendices provide further information not suitable within the format of the species accounts. These include definition of scientific terms, field identification key to the generic level, information pertaining to conservation and the study of systematics which deals with the explanation and documentation of organismic diversity, illustrations of large mammal tracks, list of general references, and index of scientific and common names.

The text is supplemented by 29 colour and 7 black-and-white plates in addition to other figures by Francois Feer covering a wide selection of mammals. There are about 500 different species of mammals found in the Neotropical lowland rainforest, for which there are almost 300 written accounts in the book with all genera covered. Most of the genera are represented by an illustration, however, the majority of the bats have only black-and-white sketches of the

head. I was disappointed with the lack of detail in the colour plates because they frequently are the first to be consulted and diagnostic features should be obvious and accurate. This was not the case for the common opossum which should have had at least the terminal half of the tail white although the caption and text were correct.

As is usually the case for books covering a broad subject matter, particularly with an area still needing further study, our knowledge of basic biology of many species is lacking and perhaps justifies a generic account for the terrestrial spiny rats, a group that may include over 20 different species. Likewise, the bats are summarily handled to genus, however, some could have warranted separate species accounts (e.g., bulldog bats). This decision was probably a space constraint because there are over 100 species of bats which would have made the book unwieldy in the field.

I have already consulted this book freely during two trips to Guyana and found it very useful. The presentation and wealth of information contained in this field guide is outstanding and will satisfy the needs of both the "tourist" and "researcher" travelling to the Neotropics.

BURTON K. LIM

Department of Mammalogy, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6

Interpretation and Explanation in the Study of Animal Behavior

Edited by Marc Bekoff and Dale Jamieson. 1990. Westview, Boulder, Colorado. 2 volumes, xxvii + 505, illus., and xxvii + 465 pp., illus., U.S. $45.00 each.

How objective are our studies of animal behaviour? What significant evolutionary accounts can we generate? To what extent can we understand the worlds of other species? What features are we justified in attributing to them? What moral obligations do we owe them? Is Lloyd Morgan's canon a loose one? These are some of the difficult, important, and current questions under scrutiny in this work. Following a foreward by Griffin predictably urging greater attention to the study of animal mentality, the 21 chapters of the first volume are clumped into four groups. In the first, and strong, group, on interpretation and understanding, Fentress examines the problems of the categorization of behaviour, Bernstein and Galef provide tough-minded analyses of animal relationships and traditions respectively, Gruen evaluates three feminist critiques of gender-biased knowledge, and Fisher untangles several senses of "anthropomorphism". The second group, on recognition, choice, and play, seem scarcely related to each other or to the theme embodied in the title. In particular the two chapters on play are very much at odds. (And does "self tickling" really exist as claimed?) If, as the editors aver, this set of topics is the most likely to provide empirical support for the existence of animal minds, then cognitive ethology is indeed the non-starter that we skeptics maintain. The third group, on communication and language, is a mixed bag with some tangential material but interesting chapters by Herman on semantic and syntactic comprehension by dolphins and Sue Savage-Rumbaugh on language skills in pygmy chimpanzees. The chapter by W. John Smith, when contrasted to his justly influential 1977 book, indicates the intervening influence, but not benefit, of cognitive lingo. Wilder doubts that cuing of experimental animals, as in the famous case of the turn-of-the-century German horse Clever Hans, can ever be excluded, but in her preceding chapter Savage-Rumbaugh assures us that "this is patently false". The fourth group, on animal minds, is philosophically the most demanding, drawing on most major figures between Descartes and the Churchlands. Not surprisingly the contributors differ over the extent to which animals enjoy mental powers and to which we can understand other species. Crisp confuses clades and grades, and unsuccessfully criticizes the theory of Nicholas Humphrey, relating consciousness to social interaction, which is the best in this problematical field. Dupré astoundingly asserts that behaviourism has been unsuccessful, and Clark concludes the volume in a fog of poetic nonsense.

The 17 chapters of the second volume are clumped into three groups. Among the first group, on explanation and confirmation, Burkhardt reviews historical practice, Wynn considers tool behaviour, and Byers and Bekoff examine the fallacy of affirming the consequence in the theory of social evolution. Mitchell criticizes the use of "rape" by Thornhill who, in his preceding chapter, focuses on entirely other criticisms. In the second group, on method, analysis, and critical experiment, the heterogeneity includes neurobiology, artificial intelligence, phylogenetic ethology, quantitative modeling, and behavioural ecology. In an examination of experiments and hypotheses in avian dialects, Kroodsma shows the mismatch between hypotheses of interest and hypotheses actually under test. Koenig and Mumme provide a balanced account of the valid controversy surrounding the interpretation of helping behaviour. In the third group, on moral dimensions, there are chapters on domestication, ethics in genetics, and animal rights and feelings, ranging from tight analyses to emotional waffle. Some provocative matters are usefully raised, such as that by Finsen on the treatment of potential human/chimpanzee hybrids.

This fat duo of books romps around a broad landscape with bold, if inevitably uneven, strides. The style is generally relaxed, and the range of types of papers is enormous: reports of empirical research, histories, critiques of controversies, logical and conceptual analyses, advocacy of particular approaches, and emotional outgushings. As instanced above, some chapters are fine and stimulating contributions to the theme while others are at most borderline. There are several occurrences of major conflicts between successive chapters that are unreconciled by either authors or editors, and it is too generous to attribute all of this to the state of the discipline. Neither are there any overall conclusions on matters such as, ethically, what experiments are justified, or methodologically, when, if ever, the principle of parsimony is to be abandoned, and the extent to which epistemological grasp will always be short of ontological reach. There are brief biographical sketches of the authors, and indexes, but no unified bibliography. As with a job lot acquired at an auction, readers must pick through these volumes, and both treasure and trash await them.

PATRICK W. COLGAN

Canadian Museum of Nature, P.O. Box 3443, Station 'D', Ottawa, Ontario K1P 6P4

Invertebrates

By Richard C. Brusca and Gary J. Brusca. 1990. Sinauer Associates, Inc. 922 pp., illus. U.S. $47.50.

It is a long time since I was at university and had to study an invertebrate textbook in detail. I wish I had had a book as clear, comprehensive, and well written as this new text with a novel approach to the subject.

The first four chapters introduce the reader to invertebrates in general, including the "Protozoa", and to biological classification, functional body plans, development and life history related to adult lifestyle, and evolution and relationships. The final chapter summarizes the Bruscas' ideas about invertebrate phylogeny. In between, the chapters treat individual phyla, or groups of small or obscure phyla, in terms of the above characteristics. Each chapter includes a brief evolutionary and scientific history, general characteristics and current classification, body plan and organ systems, biology, and phylogeny. I like the way the authors deal with a phylum as an entity, rather than discussing each class separately. I feel that it gives the reader greater appreciation of the characteristics of each phylum than does the standard textbook. However, some of the colleagues I consulted about the book did not agree, feeling that the Bruscas' method is more confusing.

I came across remarkably few factual errors, typos, and inconsistencies. There are good general lists of recent (up to 1989) references to help the reader access the scientific literature. I have only two consistent criticisms: while the figures are excellent and for the most part very clear, they have no scale to give an idea of size, which is particularly important for unfamiliar animals. Also, there is no formal glossary: although the Index leads to the definition of most of the strange and new terms (I did notice the absence of a few), the two-step process is cumbersome and aggravating.

Obviously, no one person can critically evaluate the whole of a book on such an enormous topic. I am sure that invertebrate specialists will find something to criticize in the treatment and interpretation of their particular group, as I did, but the same would be true for a book where each phylum was treated by a specialist. As the authors point out clearly and frequently, there is much we don't know about invertebrates and much that is controversial in our interpretation especially of relationships.

Because each major phylum is given the same treatment, *Invertebrates* should be viewed as a broad reference to the group as a whole, giving access to more detailed knowledge of each group through the references. This book by the Bruscas treats a difficult, almost overwhelming, topic fairly and comprehensively. I thoroughly recommend it as a nice textbook for the serious invertebrate zoologist, and as an essential addition to libraries serving both undergraduate and graduate biology departments.

DIANA R. LAUBITZ

Collections Division, Canadian Museum of Nature, Box 3443, Station D, Ottawa, Ontario KlP 6P4

Pandas

By Chris Catton. 1990. Facts on File, New York. viii + 152 pp., illus. + plates. U.S. $22.95; $29.95 in Canada.

This is the second book devoted to pandas since Schaller et al. (1985) and at least the sixth book overall. Do we need yet another? Rather disturbingly, I found no mention of the purpose or intent for the author to write this book. Another frustrating aspect of this book is that Catton includes both Red and Giant Pandas, even though recent DNA hybridization studies have separated them phylogenetically into separate families. The two species obviously have important ecological and morphological similarities; however, I disagree with Catton's justification for inclusion of both species and believe they are better treated separately than incorporated into the same book.

The book contains six chapters, three appendices, a bibliography, and an index. Chapter 1, "The First Pandas", describes the evolution of western knowledge of pandas and acquisition of the first panda specimens. It provides an excellent summarization of the panda's role in eastern cultures. Also of interest is the variety of names provided each species by different cultures throughout their respective geographic ranges.

Chapter 2, "Panda Country", describes each species' geographic range, habitat, bamboo life history and role as a food source, and the formation and function of panda reserves. Chapter 3 describes dietary adaptations, foraging behaviour, food habits, utilization areas, activity patterns, and phylogenetic relationships between Red and Giant pandas. Chapter 4 discusses social organization and behaviour, reproductive strategies, maternal care, and development of young. Chapter 5 summarizes the captive breeding program and its potential role in augmenting or reestablishing viable populations in the wild. Chapter 6 overviews conservation strategies required to ensure survival of viable populations, including minimum population size, maintaining genetic diversity, habitat protection, and illegal trade.

Appendix I attempts to clarify bamboo synonymy used in three major studies. Appendix II lists bamboo species from past studies that have been identified in the panda's diet; however, it is unclear whether the list is for Red Pandas, Giant Pandas, or both. Appendix III provides a list of Giant Pandas exported from China to foreign zoos. The bibliography is complete, providing an avenue for those interested in additional information. The index, although quite good, would be more useful if the subheadings listed separately under Red and Giant Panda were also listed as primary headings with each species listed as subheadings. Included are 19 color plates, some of which are quite good. Twenty-one figures of varying quality are used to accentuate the text, some of which are unnecessary. For example, I find little reason for including figure 21, a poor rendition of a male musk deer. Figure 8 could be improved by incorporating some sort of scale to better appreciate the skulls' actual sizes.

The format of the book is very attractive. I found no typographical errors although the word "after" is missing from page 74, paragraph 2, sentence 4. Catton's writing style is clear and somewhat anecdotal, providing pleasurable reading. This reasonably priced book is suitable for lay readers, yet provides enough technical information to be useful to the scientific community. This book is intermediate in scope between Schaller et al. (1985) and Roots (1989). Overall, *Pandas* will be useful to a wide variety of individuals interested in these popular, yet little known carnivores.

Literature cited

Schaller, G. B., J. Hu, W. Pan, and **J. Zhu.** 1985. The Giant Pandas of Wolong. University of Chicago Press, Chicago, Illinois. 298 pages.

Roots, C. 1989. The bamboo bears: the life and troubled times of the Giant Panda. Hyperion Press, Winnipeg, Manitoba. 102 pages.

JERROLD L. BELANT

State University of New York, College of Environmental Science and Forestry, Adirondack Ecological Center, Newcomb, New York 12852

Present address: U.S. Department of Agriculture, Denver Wildlife Research Center, 6100 Columbus Avenue, Sandusky, Ohio 44820

Mammals of Oklahoma

By William Caire, Jack D. Tyler, Bryan P. Glass, and Michael A. Mares. 1989. University of Oklahoma Press, Norman. 544 pp., illus. U.S.$29.95

Mammals of Oklahoma is one of a number of recently published state mammal accounts. Oklahoma was one of the few remaining states lacking a comprehensive account of its native mammals. As stated by Caire: "The primary objective of this book is to acquaint the public with the mammals of Oklahoma. At the same time, sufficient technical information is included to be useful to the professional mammalogist." I feel the authors have adequately met this objective.

This book is unusual in that each of the chapters was written by an individual author or combination of authors, instead of the typical "consolidated approach." Although this approach is probably more convenient for the authors, cohesiveness of the book is decreased by different writing styles and inconsistent editing.

The book is divided into two parts. Part one includes an introduction, history of mammalogy in Oklahoma, physiognomic regions of the state, zoogeographical affinities of these mammals, glossary, an illustrated identification key, and a checklist of mammals of Oklahoma. Part two consists of species accounts, divided into eight chapters by order and including additional chapters on species of unverified occurrence [*Mustela nivalis* has since been recorded in Oklahoma (Clark and Choate, 1988, Prairie Naturalist 20: 134) and *Sorex longirostris* was reported (Taylor and Wilkinson, 1988 Southwestern Naturalist 33: 248.)], and domestic and exotic species.

Each species account is two to five pages long and contains a pen-and-ink drawing (of varying quality) and a distribution map. The distribution maps would be of greater use if approximate ranges were incorporated, similar to the cross-hatching used in species accounts of *Antilocapra americana* and *Ursus arctos* to present their probable historic ranges. Harvest records are included for furbearing species. Species accounts begin with common and scientific names, followed by morphology, distribution and natural history. Overall, a thorough literature review of pertinent information from Oklahoma and adjacent states was used to support the text.

Three appendices are also included. Appendix one gives locality information for the 19 228 specimens examined, appendix two contains an etymology of scientific names of mammals listed in the text, and appendix three contains a list of scientific names of plants mentioned in text. Also included is a highly functional index.

Several of the scientific names Caire et al. used are now out of date, although alternate names used are explained in the introduction. As with any other comprehensive account of this magnitude, *Mammals of Oklahoma* is not error free. I found a number of minor errors that detract from its overall quality, most of which could have been eliminated by more rigorous editing by the co-authors. For example, in the introduction. *Odocoileus* is stated as preferred to *Dama* (Hall, 1981, *The mammals of North America,* Second edition, John Wiley and Sons); however in *O. virginianus* species account, *Dama* is used rather than *Odocoileus*. Many citations are not included in the literature cited, and a considerable number of typographical errors are present.

Ending on a positive note, the authors have completed a major contribution in Oklahoma mammalogy. I believe this reasonably priced book will serve as a useful reference to Oklahoma mammals. It is a must for students of mammalogy and individuals interested in the fauna of the Southwestern United States.

JERROLD L. BELANT

State University of New York, College of Environmental Science and Forestry, Adirondack Ecological Center, Newcomb, New York 12852

Present address: U.S. Department of Agriculture, Denver Wildlife Research Center, 6100 Columbus Avenue, Sandusley, Ohio 44870.

The Natural History of Seals

By W. Nigel Bonner. 1990. Facts on File, New York. 196 pp., illus. U.S. $24.95; $33.95 in Canada.

This is a popular book by a highly qualified author. Bonner recently retired after 35 years of working with marine mammals, including stints as head of the Seal Research Unit of the British Natural Environment Research Council and in senior jobs with the British Antarctic Survey.

Any naturalist who spends time near the sea will find the book interesting and informative. It deals with all the world's seals, and describes their lives, their adaptations (anatomical and physiological) to the marine environment, their senses, their social systems, and their evolution. This occupies a little over half the book. The second part deals with interactions between seals and people: the history of seal hunting, the consequent fluctuations in seal popula-

tions, the uses made of seal products, the damage seals do to fisheries, the effects of marine pollution on seals, seals as hosts of codworms, Greenpeace's successful anti-sealing campaign, the conservation of seals, seal watching as part of ecotourism, and much more.

The book is about seals *sensu stricto*, that is true seals, of the family Phocidae. Other pinnipeds – sea-lions and fur seals (Otariidae), and walruses (Odobenidae) – are excluded. For Canadian readers, this is disappointing; to exclude from the book the sea-lions and fur seals of our Pacific coast, and the walruses of our Arctic seas seems arbitrary. Bonner's reason is that the order Pinnipedia may be evolutionarily artificial: according to many paleontologists the terrestrial ancestors of the Phocidae were not closely related to those of the other pinnipeds, and their similarities stem from convergent evolution.

The book is for naturalists rather than professional scientists. The occasional lapses into technical report style are too few and too short to matter. There are some quaint archaisms: Inuit are called Eskimos; humanity is called Man (with capital M); and the fish-store customer who comes across parasitic worms in a cod fillet is described as "the housewife"!

But these are trivial complaints. The book is full of interesting material: for example, on how seals conserve oxygen for long dives, on how they avoid the bends, and on how they fast for long periods. The author's opinions on seal conservation and the future prospects for various species give much food for thought.

It is a pleasure to have these subjects discussed dispassionately. Here is his concluding opinion: "No sensible person can be optimistic about the future for the human race or for many of the higher animals with which we share this planet. But things are perhaps a little brighter for seals than for some other mammals." The author does not say whether this is good news or bad. The book has a useful bibliography and a full index. It is a book to refer to again and again.

E. C. PIELOU

R.R.1, Denman Island, British Columbia VOR 1TO

Protecting Internationally Important Bird Sites: A Review of the EEC Special Protection Area Network in Great Britain

By David A. Stroud, G. P. Mudge, and M. W. Pienkowski. 1990. Nature Conservancy Council, Northminster House, Peterborough PE1 1UA, U.K. 230 pp. £17.

Which European Economic Community (EEC) country has set aside (a) the highest (22%) and (b) the lowest (0.52%) proportion of its total area as Special Protection Areas (SPA) for birds? Did you guess (a) Denmark and (b) Britain?

The EEC Council issued a Directive on the conservation of wild birds in 1979 requiring its 12 member states to set up SPA's for vulnerable species and for migratory species. In 1988 the Nature Conservancy Council was asked by the British government to review the extent to which the proposed SPA's in Britain met the EEC Directive. This publication is their report. It contains a wealth of information: population, habitat, and site maps with discussion; a dictionary of common bird names in seven languages; a detailed description of the "Bezzell Index" (a system producing indices of vulnerability of species); and international legislation. The British Isles provide vital wintering grounds for geese and wildfowl breeding in Northern Canada, Greenland, Iceland, and northern Europe, equally vital staging areas for migrating waders, and habitat for breeding seabirds (gulls, auks, petrels, etc.). The criterion for an SPA site is that it should contain at least 1% of the species international population: the total world populations of Greylag, Barnacle, Pink-footed, and Greenland White-fronted geese winter in the U.K. There are 48 vulnerable species breeding or wintering in Britain, and a further 71 regularly occurring migratory species. An extensive appendix details the conservation status, habitat, population, and distribution for each one. As well, a case is made for protection of small British populations of birds plentiful elsewhere as insurance against population crashes.

The NCC concludes that a good start has been made but the U.K. "could do much better". For example, the map showing concentrations of estuarine birds is ominously similar to the map showing potential land-claim schemes. This is an informative report and useful model for Canadian conservationists. It is sobering that the initial aim is to provide protection for at least 1% of bird populations. Suppose this was a goal for preserving human populations? It would mean that about 260 000 Canadians would be protected!

JANE ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T6

Seabird Status and Conservation: A Supplement

Edited by J.P. Croxall. 1991. ICBP Technical Publication No. 11. Page, Norfolk, England. vi + 308 pp., illus. £17.50.

This volume is a supplement to the 1984 International Council for Bird Preservation's *Status and Conservation of the Worlds seabirds*. It is meant to fill in gaps or strengthen the weak areas of the original volume. It contains 15 papers covering about 9 countries and some offshore islands.

Each paper gives a brief description of the area covered, species accounts for at least the identified breeding birds and comments on abundance and conservation. Despite the intent to "fill in the gaps" the amount of information given varies enormously. For example Sri Lanka's contribution is just three pages of text. The section on British Columbia is 17 pages of text plus 34 pages of maps and tables. Clearly there are still areas where much needs to be done and these lie mostly in the less-developed countries.

Despite this variation in detail the book gives informative, added insight to the status of many seabirds. The news, however, is not often good news. Humans continue to assault their environment and seabirds are among the most vulnerable of creatures. North Americans will be most interested in the accounts covering Hudson Bay, the Great Lakes, British Columbia, and California, which are also the most detailed and informative of the papers.

What is a little more surprising than the information given is what is not said. The two Russian papers, for example, do not make any negative comments. Typically the western nations will say that populations have been adversely affected by pollution, disturbance, etc. The developing nations frequently quote poaching and lack of enforcement as problems. The U.S.S.R. is the only country where seabird populations "appear satisfactory". The eastern bloc's enormous pollution problems, bad resources management, and chronic need for cheap food have received much publicity of late. Have these factors not influenced vulnerable species like the Arctic Tern? The text is not at all helpful.

The Brazilian paper states that there is no conservation problem for the Olivaceous Cormorant. However the main breeding colonies are in the Pantanal, an area now threatened by mine pollution, a massive increase in tourist development, poaching, and the import of exotic species like crocodiles. This apparent omission may simply be a question of timing, as these pressures have only become significant in the last two years, probably after the paper was written.

Again timing may be the answer for another omission, but I thought some of Blokpoel's work on artificial nesting platforms for terns would have been worth including. A final minor criticism is the level of grammatical editing could be improved, but this rarely interferes with the sense.

The book is a useful addition to the collection of the serious birdwatcher, especially those with a deep interest in seabirds. For the professional researcher it is a must.

ROY JOHN

Nolan, Davis and Associates, 7020 Mumford Road, Halifax, Nova Scotia B3L 4S9

Backyard Bird Song

By Richard K. Walton and Robert W. Lawson. 1991. Peterson Field Guides. Houghton Mifflin, New York. 32 pp., illus. + cassette tape. U.S. $19.95.

This is an enjoyable introduction to identification of birds by their songs and calls. It is recommended for both the beginning birder, like myself, and the young naturalist. Both the text and the audio discussions are very simple and yet quite informative. They describe 28 species of bird, with a variety of songs or calls for each and three mammals which make bird-like calls. This is certainly enough for a beginner to start with. More experienced birders are advised to go to the more comprehensive, three tape versions by the same authors: *Birding by ear: western* (1990) which describes 91 species, and *Birding by ear: eastern and central.* (1989) which describes 85 species of birds' sounds. Both are also published by Houghton Mifflin. The latter was reviewed in *The Canadian Field–Naturalist* 104(2).

I found the presentation excellent with an easy to listen to and remember style. The use of phonetic and other memory guides was also useful for the beginner. I did think that some of the 28 bird species chosen are relatively simple to identify without instructions. Surely everyone knows a Blue Jay, American Crow or Mourning Dove. However, I was surprised to learn the Black-capped Chickadee has a song which is so different from its well known call. For Canadians, and especially those who do not live in our southern Carolinian fringe, several of the species, such as Carolina Chickadee, Carolina Wren, Northern Mockingbird, and Tufted Titmouse, are not apt to be common backyard species.

The guide book provided a short description of each of the species, along with a colour picture. It was completed by a bibliography, phonetic index and alphabetic index. It will provide a good reminder when practising the newly learned listening skills outside in your back yard.

WILSON EEDY

R.R. 1, Moffat, Ontario LOP 1JO

The Biology and Evolution of Australian Lizards

By Allen E. Greer. 1989. Surrey Beatty and Sons Pty Limited, Norton, N.S.W., Australia. xvi + 264 pp., illus. A $60 plus postage.

The fauna of Australia has long held a special allure for biologists in other countries and this is no less true for the herpetofauna than for other elements. For me, this book was timely, arriving as it did just as I was contemplating the Second World Congress of Herpetology, which is to be held in Australia in late 1993. It successfully whetted my appetite and I am ready to leave immediately!

In this book, Greer's aim is to "...attempt to summarize the biology of Australian lizards against the background of their evolutionary relationships." He does this in seven chapters (plus an Introduction): one on phylogeny and geographical origins, one for each of the five families of lizards that occur in Australia, and one on snakes. This last chapter, though brief, is an imaginative addition to a book on lizards and has the effect of completing the phylogenetic picture. The meat of the book, however, is in the five chapters on the lizard families. Each (except for the one on varanids) consists of a general introductory part followed by a section on lineages, essentially a species-by-species description of the family. Each species account is somewhat like a field guide entry, and synopsizes whatever is known about the biology of the particular lizard. Unfortunately, these entries run together in one continuous text, making it difficult to browse. Also, discussions of interesting biological phenomena (e.g., parthenogenesis) are buried in the species accounts, but the index is not adequate to deal with all of them (e.g., running speed). There is a heavy emphasis on cladistic relationships and anatomy, but there is a lot of interesting natural history as well. The illustrations are excellent, consisting mainly of colour photographs of lizards and line drawings of anatomical features. Each chapter concludes with several tables summarizing published information on various aspects of the biology of Australian lizards in that particular family (e.g., derived characters, body temperatures, clutch sizes); these are potentially very valuable sources of information. On the more curious side, Chapter 1 contains an extraordinary (and excessive, in my view) diatribe against historical zoogeographers.

This book is an excellent reference work, but I found it hard to read from cover to cover, mainly because of the technical nature of much of the material. However, it does have its humorous moments (e.g., the concise recipe for cooking goannas on page 205). Unfortunately, although it is visually appealing, it is also sloppily produced. My copy included a full page of errata, but I found several more typographical errors; furthermore, the errata themselves contain errors. All in all, the final product would have benefited from more careful proofreading.

Despite its imperfections, I liked this book because it taught me a lot about lizards with which I was unfamiliar. Those who want a more general introduction to lizards might do better to go elsewhere, but they could do much worse than to consult Greer.

PATRICK T. GREGORY

Department of Biology, University of Victoria, Victoria, British Columbia V8W 2Y2

Life History and Ecology of the Slider Turtle

Edited by J. Whitfield Gibbons. 1990. Smithsonian Institution Press, Washington, D.C. xiv + 368 pp., illus. U.S. $ 60.

It seems to me that the slider has a special significance for North American herpetologists. Many of us were at least partly attracted to this field of study by keeping tiny pet-store "red-ears" as children. The wild animal, though, is far more interesting than the captive animal. It was therefore with eager anticipation that I opened this volume.

The main focus of this book is not the Red-eared Turtle but one of its sister subspecies, the Yellow-bellied Turtle, with excursions into the biology of other turtles, including red-ears. There are 24 chapters by Gibbons and 32 other contributors, divided into six sections representing different areas of ecology and systematics. Overall, there are strong emphases on life history theory and on long-term field studies. The latter are highlighted by the results of 20 years of study of sliders and other turtles by Gibbons and his colleagues in South Carolina.

This book consists of a fairly eclectic and somewhat uneven collection of articles. Most chapters are really review articles, but a few (e.g., Parker's chapter) are reports of original research that look like they belong in journals. In general, I found the review chapters, particularly those with a broader perspective, more rewarding. I especially liked the treatment of growth by Dunham and Gibbons, which will be of great value to those studying growth in almost any kind of animal. Similarly, Frazer et al. provide a textbook example of the difficulties in con-

structing a life table for a natural population and how to go about it. Other chapters, notably those on systematics, are necessarily more specific, yet nonetheless interesting.

For the most part, this book is well-written, although there are frequent anthropomorphisms in the chapters by Congdon and Gibbons. On the other hand, Gibbons writes in an easy, anecdotal style that makes the reader want to keep reading. He apparently gave his contributors considerable latitude in writing style and even in choice of what to call the slider (*Trachemys scripta* or *Pseudemys scripta*); in Chapter 1, he gives a humorous guide to the various possible pronunciations of these generic names. There are, not surprisingly, a few overlaps between chapters and occasional disagreements (e.g. Ernst and Legler differ in the number of subspecies of sliders that they recognize). The book has only a few obvious errors (e.g., the incorrect conversion of acres to hectares on page 31). The Figures and Tables are generally well-produced and informative.

The slider ranges over about 77° of latitude. By any criterion, it is a very successful species. Gibbons' book was equally successful in stimulating my interest in this animal.

PATRICK T. GREGORY

Department of Biology, University of Victoria, Victoria, British Columbia V8W 2Y2

Sharks, Sharks, Sharks

By Tina Anton, illustrated by Grace Goldberg. 1989. Raintree Publishers, Milwaukee. 31 pp., illus. U.S. $12.33.

Sharks and Whales

By Burton Albert, illustrated by Pamela Johnson. 1989. Grosset and Dunlap (Canadian distributor Putnam, Mississauga). Revised Edition. 42 pp., illus. U.S. $7.95.

Whales and sharks are ever popular with younger readers for their size and/or their perceived ferocity. There are many books on the market with these interesting organisms as topics; choice of book is often a matter of a personal taste by the adult or child in the manner of presentation.

Both these books have text in short paragraphs with accompanying colour drawings as illustrations of that text. Colour photographs are preferred by some young readers. Each book deals with a selection of shark or shark and whale species in a mixture of factual and narrative styles. Both deal with some species found outside North American waters but there is usually no indication of where these fish and mammals can be found.

The first book discusses various aspects of shark biology in short, mostly simple, sentences. There are 14 text and 14 facing illustration pages. The book is meant to be read by or to a younger age group. In general this format and content succeeds. Occasionally words are used which may baffle a youngster, such as lab instead of laboratory. There are as few as three sentences for a total of 24 words to as many as eight sentences and 99 words with most falling in between these two extremes. There is some standardisation of drawings, e.g. same gill slits on dissimilar species, but generally the drawings are accurate at this level of presentation. Some errors do crop up in the text. Scientists do know how sharks got into a lake (the bull shark in Lake Nicaragua has been studied quite extensively). Calling placoid scales "teeth" is a little confusing when teeth are modified scales. The attempt to explain the acousticolateralis system does not succeed at this reading level – some biological systems are too complex to summarize briefly. Not all sharks necessarily sink (hepatic floats, air ingestion).

The second book leads off with sharks and follows with whales. There are 26 shark and 23 whale species described. The information presented here is for an age group somewhat older than the first book. Sentences are longer, grammatically and informationally more complex, and words are more varied. The drawings here are too murky and have none of the light found in the sea (BWC) but they were preferred over the first book (NPC). The text is often a little too coy, e.g., "The great white, you see, stops at nothing". A young reader found it full of new and interesting information but lacking the concentrated detail needed for school projects even at the elementary school level. There are some errors of fact or explanation. The sleeping shark is not a distinct species like others dealt with here but a behaviour. Sand tigers are not the only sharks to show uterine cannibalism and oophagy. The basking shark is riding remarkably high out of the water. The whale shark rinsing its mouth by adopting a vertical position is more likely to be a feeding mechanism.

Both books would find favour with young readers simply on the basis of their content. They would be read for interest rather than as a resource, and as this is probably their intent they fulfil their purpose.

BRIAN W. COAD and NICHOLAS P. COAD

Canadian Museum of Nature, Box 3443, Station D, Ottawa, Ontario K1P 6P4

BOTANY

The Rare Vascular Plants of the Island of Newfoundland

By André Bouchard, Stuart Hay, Luc Brouillet, Martin Jean, and Isabelle Saucier. Syllogeus No. 65, Canadian Museum of Nature, Ottawa. 165 pp., illus. $7.95 plus postage.

I am generally very pleased with the content and layout of this book. The introduction is useful, unusually long, and illustrated with 16 maps and one figure. The rare plants are listed alphabetically and annotated with synonyms, information sources, a distribution range, districts of the island where found, published map reference, habitat, ecoregions of the island, rarity status in Canada and rarity on the island of Newfoundland. The authors use definitions of rarity as set up by the Nature Conservancy of the United States (1982 and 1988) and the *Rare Plants of Canada* (Argus and Prior 1990). The complete Reference Cited covers nineteen pages, yet are not entirely exhaustive. For example, *The Osprey* magazine is rarely cited and Green's list (1984) was missed. Appendix I has a three page list of excluded species. Appendix II lists the plants in taxonomic sequence by family. There are 271 individual dot-maps for the rare plants at the end of the text which should have been listed as Appendix III. The maps and dots are clear and crisp and appear to be computer generated.

This book covers only half the Province as Labrador has been left out! This causes a number of problems. For example Bouchard et al. (1989) list many species which are rare on the island but quite common in Labrador and therefore Provincially common. We have the reverse problem as well, plants that are apparently rare in Labrador but much more common on the island. In the meantime readers can consult Rousseau (1974) for maps of Quebec and Labrador.

I have a major problem with the authors deciding to entirely leave out data about plant distribution on the islands of St. Pierre and Miquelon. Politically they are French, but geographically and biologically they are part of the Newfoundland islands and this book was intended to be a bio-geographic work. To omit St. Pierre and Miquelon is to omit the work of Arsene (1927); Fernald (1950); Scoggan (1978); and Rouleau (1978) [and soon to be published maps] as well as recent efforts by Roger Etcheberry. It is particularly unfortunate because the islands have been well botanized and have many plants of southern affinity which are rare for the Province, for example *Myrica pensylvanica* (Bayberry), *Mitchella repens* (Two-eyed Berry), *Elymus virginicus* (Virginia Wild Rye) and *Gaultheria procumbens* (Aromatic Wintergreen). *Carex languginosa* (Wooly Sedge) and *Laportia canadensis* (Canada Wood-Nettle) are presently known from St. Pierre-Miquelon but not the island of Newfoundland. Damman (1965, 1976) and Robertson (1984) also omit the French Islands on their distribution works and this is a trend I hope will not continue as the information is poorly known and is critical to a realistic understanding of regional phytogeographic features and the context of the concept of rarity.

The cover has a fuzzy photograph of a rugged Newfoundland coastal scene. A locality for the photograph was not given by the museum. The book is only partly translated into French (pages 43 to 109 not at all), although this is probably an economic compromise.

The distribution maps are not printed beside the pertinent information, but separately at the end of the book, and this is an inconvenience. When the distribution for Newfoundland is provided the information is limited to the Provincial Districts. This means it will be very difficult for readers to relocate these plants on the ground without also using the data base published by the Provincial Department of Culture, Recreation and Youth (Bouchard et al. 1989). I have been informed, in correspondence with the Lands Branch, that copies are very limited.

There are a few typographical errors (see line 2 of page 73); however, I did not really go through the manuscript with a fine-toothed comb.

Even while this book was being printed new records of plants were being made. *Eleocharis nitida* (Neat Spike Rush) was found at the head of Bay d'Espoir, *Elymus virginicus* was found at the head of Connaigre Bay (Day 1991) and *Phrgmites australis* (Water Reed) was discovered in Stephenville. Certainly, there is much more to explore and do, and I encourage readers to obtain and use this book as a guide in their searching.

Literature Cited

Argus, G. W., and **K. M. Prior.** 1990. Rare Vascular Plants in Canada, our natural heritage. Canadian Museum of Nature. Ottawa, Ontario.

Arsene, L. 1927. Contribution to the Flora of the Islands of St. Pierre et Miquelon. Rhodora 29: 117–133, 144–158, 173–191, 204–221.

Bouchard A., S. Hay, L. Brouillet, P. Jutras, C. Gautier, I. Saucier. 1989. Data base for Rare Vascular Plants of Newfoundland. Research Contract with The Ministry of Culture, Recreation and Youth, Government of Newfoundland and Labrador, Department of Environment and Lands. 94 pages.

Damman, A. W. H. 1965. The distribution patterns of northern and southern elements in the flora of Newoundland. Rhodora 67: 363–392.

Damman, A. W. H. 1976. Plant distribution in Newfoundland especially in relation to summer temperatures measured with the sucrose inversion method. Canadian Journal of Botany 54: 1561–1585.

Day, R. 1990. Newfoundland plant collection, 17–24 August, 1990, mostly from Hermitage and Port au Port areas. The Osprey 21(4): 172–175.

Fernald M. L. 1950. Gray's Manual of Botany. Eighth edition. American Book Co. 1632 pages.

Green, I. J. 1984. A collection of Vascular Plants of Insular Newfoundland. Agriculture Canada and Department of Rural, Agriculture and Northern Development, Government of Newfoundland and Labrador. 81 pages.

The Nature Conservancy U.S. 1982. Natural Heritage Program Operations Manual, with revisions through 1988. The Nature Conservancy, Arlington, Virginia.

Robertson, A. 1984. *Carex* of Newfoundland. Newfoundland Forest Research Centre, Box 6028, St. John's Newfoundland. Canadian Forestry Service. 252 pages.

Rouleau, E. 1978. Rouleau's List of Newfoundland Plants. Memorial University's Oxen Pond Batonic Park. St. John's Newfoundland A1C 5S9. 132 pages.

Rousseau, C. 1974. Geographie Floristique Du Quebec/ Labrador. Les Presses de l'universite Laval, Quebec city. 799 pages.

Scoggan, H. J. 1978. The Flora of Canada. 4 Volumes. National Museum of Natural Sciences, Publications in Botony 7. Ottawa, Ontario.

ROBIN DAY

12-404 Elgin St., Ottawa, Ontario K2P 1N3

Fungi on Plants and Plant Products in the United States

By David F. Farr, Gerald Bills, George Chamuris, and Amy Rossman. 1989. APS Press, St. Paul, Minnesota. 1252 pp. U.S. $59. in the USA, U.S. $74 elsewhere.

The book, a technical reference text, is an up-to-date directory to the literature on fungi which attack plants or plant products in the United States. It is composed of three major sections: the Host-Fungus Index, the Fungus List, and the Literature Cited. Other sections are the Host Index, the Common Name Index, the Fungus Index, and a list of Authors of Fungal Names.

The Host-Fungus Index, 548 pages long, is the core of the book. It lists the plant families, alphabetically, and within each family the genera are listed alphabetically. Under each genus is a list of the fungi which occur on each species in that genus. Each fungus listed is accompanied by the State(s) where each fungus-plant association has been found, and the citation of the pertinent scientific report. For example, for the plant *Ledum groenlandicum*, Labrador Tea, page 174 lists the sixteen fungi reported and these range from Alaska to New York.

The Fungus List, 472 pages long, lists alphabetically the fungus genera and within each genus the species are arranged alphabetically. Accompanying each fungus species are notes on its distribution and host plant genera. For example, on page 932, the common plant disease fungus *Rhizoctonia solani* is reported to attack over 400 plant genera.

The Host Index lists the generic names of the plants and the pertinent page number. It was necessary because to use the Host-Fungus Index the user must know the family in which the genus of interest occurs. The Common Name Index lists some common names of the plants and the pertinent page number, a courtesy which allows the user to find a plant without knowing the scientific name. Finally, the Fungus Index lists the fungus species names and the pertinent page number in the Fungus List.

The book is an excellent example of the flexibility that a computer brings to the sorting and rearranging of a large volume of data. As a systematist, mycologist, and sometime plant pathologist, I have found continual use for this volume for a variety of purposes. In addition, the data are on-line and I have been able to obtain, through the courtesy of Dr. David Farr, printouts of the data rearranged to suit my purposes.

There is no doubt that this book will be a standard reference for years to come. Its appearance at a time when we are beginning to recognize the lack of baseline data, for biological surveys and biodiversity studies dealing with the fungi, will increase its importance as a basic point of reference.

J. GINNS

Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario K1A 0C6

Discovering Wild Plants, Alaska, Western Canada, and the Northwest

By Janice J. Schofield. 1989. Alaska Northwest Books (GTE Discovery, Bothell, Washington). 12 + 359 pp., illus. Cloth U.S. $34.95, $43.95 in Canada; Paper U.S. $24.95, $29.95 in Canada.

This is an interesting introduction to useful plants found in far western North America and a cook book. According to the author "This book is written for those who have lost touch with their herbal roots, as well as those who wish to expand their knowledge of Northwest plants".

Actually only a very limited number of plants are treated, many of which are quite common, relative to the number that are known to occur in Alaska, Yukon, British Columbia, and the northwestern United States. These are plants in which man has, or has had historically, a particular interest: medicinal, food, herbal, cosmetic, dyes, etc. Those treated are organized by habitat, so that an individual looking at plants in a woodland, wet places, grassy meadows, tundra, sea shores, etc., might find various plants occurring in a particular habitat adjacent to each other in the book.

The author has gathered together considerable information on the species under consideration. This includes common names, scientific names, family names, habitat and range (but the ranges are only for the area treated and do not in most instances give the overall range of widespread species, e.g., circumpolar, circumboreal, introduced from Eurasia, etc.), what parts can be used and for what purposes, when the required parts should be harvested, what parts are poisonous or otherwise detrimental, and recipes in which they can be utilized. The species are illustrated by colour photographs, which for the most part are very good, and with one exception appear to be well identified – the photograph of *Equisetum* may actually portray two species, *E. arvense* and *E. pratense*. Line drawings, which more readily portray the parts of the plants required for identification, also accompany the text.

For those interested in expanding their knowledge of useful plants, this book contains a wealth of information. As the author points out from time to time throughout the book, however, some species should be used in very moderate quantities, some may cause allergic reactions, and there are look-alike plants that are poisonous. It is therefore, most important that individuals making use of the plants they find in the wild should first be absolutely certain these plants are positively identified and that they use only the correct parts and in specified quantities.

WILLIAM J. CODY

Centre for Land and Biological Resources Research, Agriculture Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6

ENVIRONMENT

Agroecology: Biological Resource Management

Edited by C. Ronald Carroll, J.H. Vandermeer, and Peter Rosset. 1990. McGraw-Hill, New York, Scarborough. (641 pp., illus. U.S. $89.95; $130.95 in Canada.

Agricultural ecology has received a lot of attention in the last few years. This interest will continue to increase with continued development of "sustainable" agricultural practices.

The stated goals of *Agroecology* are to provide: "(1) an overview of what the field is about, (2) a rather sophisticated introduction to main currents of thought, and (3) a critical attitude with regard to both the scientific and sociopolitical aspects of this rapidly developing field". The editors have achieved the above goals by arranging the book in four parts. They started first with a general overview followed by sections dealing with the ecological background, specific management questions, and finally a section covering areas requiring further research.

The book provides good coverage of plant, insect, and disease dynamics in agroecosytems but falls short in a few key areas. In its attempt to cover the entire field, soil organic matter, and nutrient cycling issues are inadequately covered. When one checks the index, nutrient cycling is given only a single citation. Also, the possible ecological potential of biotechnology to agroecology is not discussed.

I found of particular interest the final two chapters: the critical analyses of the modern agricultural institutions, and failure to serve farmers and consumers around the world. The discussion in these two chapters address the adverse effect of Western societies on agricultural research and development in the Third World.

Even with the book's short-falls *Agroecology* will be of interest to researchers in agriculture in this age of "sustainable" development. The book provides a new look at traditional agricultural research as well as a critical analysis of past research. I believe this book will prove to be a useful reference in the years to come.

M. SCHELLENBERG

434-4th Street S.E., Swift Current, Saskatchewan S9H 3M1

Ecological Diversity and its Measurement

By Anne E. Magurran. 1988. Princeton University Press. Princeton, New Jersey. 179 pp., illus. Cloth U.S. $47.50; paper U.S. $16.95

This concise, well written, little book gives a useful summary of the development, over the last four decades, of methods of measuring ecological diversity. It is not for amateur naturalists, but for academics, ecological consultants, and government scientists who may have occasion to measure diversity and want an up-to-date review of the possible ways of doing so. The author describes the numerous indices clearly, explains how they are related to one another, and, in a 40 page appendix, illustrates with worked examples exactly how to calculate them.

The book is wholly concerned with practical matters and, as Magurran writes in Chapter 1, "does not set out to provide a discussion of ecological diversity *per se*." The final chapter, on the empirical value of diversity indices, deals with only two contexts within which they may be valuable and both these contexts (pollution monitoring and conservation) are topics in applied ecology.

Unfortunately, she fails to note the contrast between the two applications she describes. Measuring the diversity of a collection of diatoms to judge whether the water they inhabit is polluted is entirely different from measuring the "biodiversity" (tacitly assumed to encompass all living things) of, for instance, a national park. In the former case a measure of so-called alpha diversity is appropriate; this is the diversity of a small community, narrowly defined in the taxonomic sense, in which it is feasible and meaningful to estimate the actual quantities of the different species. In the conservation context this is wholly impracticable.

What is needed by conservation ecologists is an index (or indices: no rule says you have to limit yourself to just one) of so-called gamma diversity, the diversity of a "unit such as an island or landscape" to use Magurran's definition. But she does no more than define this kind of diversity (page 58), and has nothing to say on its measurement. She cannot be faulted for not telling us *how* to measure it; this book is a review of existing literature and an index of gamma diversity has yet to be devised. But she should have pointed this out and commented on it. Trying to apply pollution-monitoring methods to conservation problems is futile and the fact should be emphasized.

The book is a good, but uncritical, review of its subject. Sad to say Magurran perpetuates the myth that the famous "broken stick" model of niche size can sensibly be fitted to data obtained by sampling a community only once. It cannot. It can be fitted only to data averaged over a number of different samples from a community, and when it is so fitted the results are either nonsense or uninterpretable depending on the form of the hypothesis under test. This blunder is not excusable on the grounds that other people have been making it for years.

E. C. PIELOU

R.R. 1, Denman Island, British Columbia V0R 1T0

MISCELLANEOUS

Despite the Odds: Essays on Canadian Women and Science

Edited by M. G. Ainley. 1990. Vehicule Press, Montreal. 452 pp., illus. $19.95.

For anyone seeking insight into why few Canadian women today specialize in science, *Despite the Odds* is essential reading. Edited by Marianne Gosztonyi Ainley of Concordia University's Simone de Beauvoir Institute, the essays examine the historical experience of women in several disciplines, as well as recount and assess the careers of a number of significant, though little known, women scientists. They also discuss the contemporary situation and the various barriers (including male attitudes) that women continue to face. Overall, it is an engrossing, at times revealing, collection that goes a long way to remedy the predilection in conventional histories of science to downplay or simply overlook the role and importance of women.

Despite the Odds offers several explanations as to why women in general have remained on the margins of Canadian science. The essays describe how women rarely held positions of power or prestige, how they were paid at lower rates and at the same level for years, and how they were given few opportunities to improve their training or education. Indeed, what reinforced this situation were a set of prevailing male attitudes that believed, among other things, that women were unsuited for the strains and rigours of field work, that married women should be at home and not in the laboratory, and that women were "helpmates" and not scientists in their own right. Many women fought against this self-negation, however, and went on to make substantial contributions in such areas as horticulture, geology, and medicine. In the end though, these accomplishments

were seldom properly recognized – ironically, an outcome in keeping with the general tendency to undervalue women.

According to the editor's preface, *Despite the Odds* grew out of a desire to find reading material for a seminar on the history of women, science, and technology. Dr. Ainley is to be congratulated for making this scholarly work available to others interested in women's history in general and the history of Canadian science and technology in particular. Hopefully the next step will be a history of a scientific discipline or field that fully integrates (as opposed to "adds on") the female experience.

W. A. WAISER

Department of History, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

Sacred Mountains of the World

By Edwin Bernbaum. 1990. Sierra Club Books. (Distributor Douglas & McIntyre, Vancouver). xxv + 291 pp. illus. U.S. $50.

It is seldom that a book comes along of such photographic and literary excellence as Edwin Bernbaum's *Sacred Mountains of the World.*

Having long held an obsessive fascination for mountainous areas and for certain mountains themselves, I was immediately attracted to the title of this book and the exceptional colour photograph on the cover of the Towers of Paine in Patagonia. Many books exist on expeditions, travel, natural history, cultures, environment, or people of mountain regions, however, this is the first book I have come across that addresses mountains with the emphasis being on "sacredness" as well as covering all the aforementioned topics.

> "An exploration of cultures around the world reveals a bewildering variety of views of sacred mountains. People of different traditions revere hills and peaks as heavens, hells, gods, demons, wombs, tombs, houses, temples, animals, birds, trees, flowers – the list goes on and on."

Bernbaum explores the diverse and numerous cultures and religions with their variety of views on these sacred mountains. His writing style allows the often complex subject matter to be easily understood and he shares his own personal passion, appreciation, love and respect for the mountains with the reader. The major content explores the many mountainous regions as a whole then highlights mountains of particular significance such as Mount Everest, Ayers Rock and Mount Kilimanjaro as well as lesser known, but important "sacred peaks" within these regions.

The book gives fascinating accounts as to why Mount Kailas is regarded as the ultimate sacred mountain for more than half a billion people in India, Tibet, Nepal, and Bhutan; why pilgrims circumambulate holy peaks; why does North America's Mount Shasta arouse excitement among contemporary spiritual and mystical groups and how the Qollahuaya people of northeastern Bolivia have developed a special intimacy with the mountains on which they live.

Men and women over the centuries have been drawn to mountains for a variety of reasons. For those interested in the sport of climbing, a chapter is directed towards the "Spiritual Dimension of Mountaineering" which gives the reader insight into what motivates climbers, utilizing quotes from such renown climbers as Mallory, Muir, Young, and Herzog.

Throughout the book the subject of cultures, religious history, mythology, symbolism, art, and literature are covered with many excerpts from religious texts and writing from ancient mythology to further enhance the book's theme.

The author is an accomplished mountaineer, writer, and photographer who has travelled and climbed throughout the world. He has his doctorate in Asian Studies and is presently a university research associate specializing in Buddhist and Hindu religions and mythology. His experiences as well as his expertise have assisted in the completion of this book that proves to be a compelling read that educates and entertains. The material is well-presented and directed at the general reader providing an extensive bibliography for those interested in additional reading. Accompanying the text are over 120 superlative colour photographs, many taken by Bernbaum himself.

This is a highly recommended book that one can read time and time again and is not quickly dated. The topic of mountains are viewed through a very unique perspective and the contents will captivate both the active and armchair enthusiasts.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario K0A 2W0

YOUNG NATURALISTS

Introducing Mammals to Young Naturalists

By Ilo Hiller, 1990. Texas A & M University Press, College Station. The Louise Lindsey Merrick Texas Environment Series, 110 pp., illus.

The most immediate reaction one has when scanning over this book prior to reading it is that the author has a good knowledge of what appeals to young readers. The book is filled with numerous full-page colour photographs, excellent diagrams, and an abundance of word games and activities. The message being conveyed is evident, learning can be fun.

Introducing Mammals to Young Naturalists is the second in a series of books designed to introduce children to the wonderful and fascinating world of nature. The author has chosen to highlight eleven very different species with the focus on origins, habitat, behaviour, unusual characteristics, and the life cycle of each particular mammal. Young naturalists will learn such things as how antlers grow, that Armadillos usually give birth to same-sex quadruplets, and Porcupines have over 30 000 quills. The facts presented pique the reader's curiosity and hold one's interest throughout.

The book will provide many hours of enjoyment while following directions for making plaster casts of animal tracks, creating animal ornaments for Christmas trees, or the explicit instructions that enable one to draw animals like a pro.

This is an excellent introduction to mammals that will leave the children craving for more and eagerly awaiting the release of the next book in the series. The information is well-presented, the profiles comprehensive and the language easy to understand.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario KOA 2WO

Invertebrates

By Barbara Batulla. Wilderness Album Series. Nature stories for children. Hyperion Press, Winnipeg. 39 pp., illus. $5.95

My favourite destinations for field trips with children are ponds or streams. An old, chipped, white enamel pan, plastic bowls, aquarium fishnets, a paint brush, and a magnifying glass are tools sufficient for hours of fun, watching the antics of a strange assortment of tiny creatures, each with its own gait, moving in the confines of a container. If each child could have a copy of this delightful book to take home, to read, and to colour, then the day's activities could be extended and given a broader focus.

In one slim book, Barbara Batulla has crammed an amazing amount of interesting and accurate information on pond, salt water, and terrestrial animals as diverse as rotifers, sea urchins, and earthworms. Nineteen animals are featured. Each is introduced with a story about its behaviour, usually as seen through the eyes of children exploring the scene. This is followed by an encyclopedia-like account which gives more technical information and places the animal in both a systematic and food web context. A facing, full-page intricate black-and-white drawing completes each chapter. These pictures demand to be coloured so that the many elements surrounding the animals in their habitats can be distinguished. The colouring instructions are helpful for this and for recognizing the various animals in the field.

Children from about five to pre-teens would enjoy this book. The information is of a caliber for even older children but they are less likely to be enthused with the colouring book format. This, and probably also the other 22 titles mentioned in this series, is an excellent buy which should help to get it into the hands of suitable recipients.

FENJA BRODO

Research Associate, Canadian Museum of Nature, P.O. Box 3443, Station. D, Ottawa, Ontario K1P 6P4

NEW TITLES

Zoology

†**Alberta birds, 1971-1980, volume 1: non-passerines.** 1991. By Harold W. Pinel, Wayne W. Smith, and Cleve R. Wershler. Calgary Field Naturalists Society, 1017-19 Avenue N.W., Calgary, Alberta T2M 0Z8. 243 pp. $15.50.

†**Annotated checklist of the birds of Ontario.** 1991. By Ross D. James. Second edition. Royal Ontario Museum, Toronto. 128 pp. $13.95.

***Backyard bird song.** 1991. By Richard K. Walton and Robert W. Lawson. Peterson Field Guides. Hougton Mifflin, New York. 32 pp., illus. + cassette tape. U.S.$19.95.

†**Battle against extinction: native fish management in the American west.** 1991. Edited by Wendell L. Mickley and James E. Deacon. University of Arizona Press, Tucson. 500 pp., illus. U.S.$40.

Biology of the Koala. 1991. Edited by A. K. Lee, K. A. Handasyde, and G. D. Sanson. Surrey, Beatty, Chipping Norton, Australia. 346 pp., illus. A $78.

Birdlexi. 1991. By Santa Barbara Software, 100 Dover Road, Santa Barbara, California 93103. 1 computer disk. U.S.$49.95 plus U.S.$3 shipping.

Birds of the Strait of Gibraltar. 1991. By Clive Finlayson. Academic Press (Harcourt Brace Jovanovich, San Diego). c488 pp., illus cU.S.$52.

A colour atlas of dangerous marine animals. 1990. By Bruce W. Halstead, Paul S. Auerbach, and Dorman R. Campbell. CRC Press, Boca Raton, Florida. 192 pp., illus. U.S.$59.95 in USA; U.S.$70 elsewhere.

A complete checklist of the birds of the world. 1991. By Richard Howard and Alick Moore. Second edition. Academic Press (Harcourt Brace Jovanich, San Diego). 832 pp. U.S.$49.50

***Crane music: a natural history of American cranes.** 1991. By Paul A. Johnsgard. Smithsonian Institute Press, Washington. 160 pp., illus. U.S.$19.95.

***Distribution and taxonomy of birds of the world.** 1991. By Charles G. Sibley and Burt L. Monroe, Jr. Yale University Press, New Haven. Illus. U.S.$125.

***Ecology and classification of North American freshwater invertebrates.** 1991. Edited by James H. Throp and Alan P. Covich. Academic Press (Harcourt Brace Jovanich, San Diego). x + 911 pp., illus. U.S.$59.95.

***Golden-crowned kinglets: treetop nesters of the north woods.** 1990. By Robert Galati. Iowa State University Press, Ames. xi + 142 pp., illus. U.S.$18.95 plus postage.

The great butterfly hunt: the mysters of the migrating monarchs. 1990. By Ethan Herberman. Simon and Schuster, New York. 48 pp., illus. Cloth U.S.$14.95; paper U.S.$5.95.

A guide to the birds of Nepal. 1991. By Carol and Tim Inskipp. Second edition. Smithsonian Institute Press, Washington. 352 pp., illus. U.S.$55.

***Harp seals, man and ice.** 19091. By D. E. Sergeant. Canadian Special Publication of Fisheries and Aquatic Sciences 114. Fisheries and Oceans Canada, Ottawa. x + 153 pp., illus. $28.50 plus shipping.

The herons of Europe. 1991. By Claire Voisin. Academic Press (Harcourt Brace Jovanovich, San Diego). c320 pp., illus. cU.S.$35.

Latin American mammalogy: history, biodiversity, and conservation. 1991. Edited by Michael A. Mares and David J. Schmidly. University of Oklahoma Press, Norman./ 480 pp., illus. U.S.$49.95.

†**Looking ahead: a wildlife strategy for Ontario.** 1991. By the Ontario Wildlife Working Group. Ontario Ministry of Natural Resources, Toronto. 172 pp., illus. Free.

***The magpies: ecology and behaviour of black-billed and yellow-billed magpies.** 1991. By T. R. Birkhead. Academic Press (Harcourt Brace Jovanovich, San Diego). 272 pp., illus. U.S.$39.95.

***Moosebirds and sandpeeps: birds in and around Fundy National Park.** 1991. By David Christie. Fundy Guild, Box 150, Alma, New Brunswick E0A 1B0. 32 pp., illus. $3.95 plus 42 postage.

***The natural history of the wild cats.** 1991. By Andrew Kitchener. Cornell University Press, Ithaca. xxi + 280 pp., illus. U.S.$27.50

New world parrots in crisis: solutions from conservation biology. 1991. Edited by Steven R. Beissinger and Noel F. R. Snyder. Smithsonian Institute Press, Washington. 256 pp., illus. Cloth U.S.$35; paper U.S.$16.95.

Perspectives in ethology, volume 9: human understanding and animal awareness. 1991. Edited by P. P. G. Bateman and Peter H. Klopfer. Plenum, New York. c306 pp. U.S.$69.50.

The petrels: their ecology and breeding systems. 1991. By John Warham. Academic Press (Harcourt Brace Jovanovich, San Diego). 448 pp., illus. U.S.$59.95.

***Phylogeny and classification of birds: a study in molecular evolution.** 1991. By Charles G. Sibley and Jon E. Ahlquist. Yale University Press, New Haven. Illus. U.S.$100.

†**Reading the shape of nature: comparative zoology at the Agassiz Museum.** 1991. By Mary P. Windsor. University of Chicago Press, Chicago. 328 pp., illus. Cloth U.S.$49.94; paper U.S.$21.95.

Red data birds in Britain: action for rare, threatened, and important species. 1991. Edited by L. A. Batten, C. J. Bibby, P. Clement, G. D. Elliot, and R.F. Porter. Academic Press (Harcourt Brace Jovanovich, San Diego). 349 pp. U.S.$39.95.

***Reptiles and amphibians eastern/central North America.** 1991. By Roger Conant and Joseph T. Collins. 3rd edition. Peterson Field Guides. Houghton Mifflin, New York. xviii + 450 pp., illus. Paper U.S.$15.95; cloth U.S.$22.95. [See 105(4)]

The restless kingdom: a study of animal locomotion. 1991. By John Cooke. Facts on File, New York. 224 pp., illus. U.S.$39.95; $49.95 in Canada.

The ruff. 1991. By Johan van Rhijn. Academic Press (Harcourt Brace Jovanovich, San Diego). 224 pp. U.S.$39.95.

Season at the point: a birder's journal of Cape May. 1991. By Jack Connor. Atlantic Monthly Press (McClelland and Stewart, Toronto). 320 pp., illus. $29.95.

Shallow-water hydroids of Bermuda: the Thecatae, exclusive of Plumiularioidea. 1991. By Dale R. Calder. Royal Ontario Museum, Toronto. 144 pp., illus. $24.50.

The status of seabirds in Britain and Ireland. 1991. By Clare S. Lloyd, Mark L. Tasker, and Kenneth E. Partridge. Academic Press (Harcourt Brace Jovanovich, San Diego). 384 pp. U.S.$41.

†**Studies of high-latitude seabirds, 2: conservation biology of thick-billed murres in the northwest Atlantic.** 1991. Edited by A. J. Gaston and R. D. Elliot. Occasional Papers No. 69, Canadian Wildlife Service. Environment Canada, Ottawa. 63 pp., illus.

*†**The traveling birder: 20 five-star birding vacations.** 1991. By Clive Goodwin. Doubleday, New York. xiii + 306 pp., illus. U.S.$13.

*†**Wild animals and American environmental ethics.** 1991. By Lisa Mighetto. University of Arizona Press, Tucson. 215 pp., illus. Cloth U.S.$35; paper U.S.$17.59.

†**Wild echos: encounters with the most endangered animals in North America.** 1991. By Charles Bergman. A;lasla Mprtjwest 9GTE Doscpveru. Bothell, Washington). x + 322 pp., illus. U.S.$12.95; $15.95 in Canada.

*†**Wisconsin birdlife: population and distribution, past and present.** 1991. By Samuel D. Robbins, Jr. University of Wisconsin Press, Madison. xviii + 702 pp., illus.

Botany

A colour guide to rare wild flowers. 1991. By John Fisher. Constable (McClelland and Stewart, Toronto). 320 pp., illus. $27.95).

*†**Common poisonous plants and mushrooms of North America.** 1991. By Nancy Turner and Adam Szczawinski. Timber Press, Portland, Oregon. 324 pp., illus. U.S.$55 plus shipping.

Flora of eastern Saudi Arabia. 1991. By James P. Mandaville. Kegan Paul (Routledge, New York). 600 pp., illus. U.S.$125.

*†**Fungi without gills (Hymenomycetes and Gasteromycetes): an identification handbook.** 1991. By Martin B. Ellis and J. Pamela Ellis. Chapman and Hall (Routledge, Chapman, and Hall, New York). xi + 329 pp. U.S.$79; $99 in Canada.

*†**Liverworts and hornworts of Southern Michigan.** 1991. By Howard Crum. University of Michigan Herbarium, Ann Arbor. vii + 233 pp., illus. U.S.$18 in U.S.A.; U.S.$20 elsewhere.

*†**Mushrooms of North America.** 1991. By Roger Phillips. Little, Brown, Boston. 319 pp., illus.

*†**A natural history of trees in eastern and central North America.** 1991. By Donald Culross Peattie. Re-issue of 1948 edition. Houghton Mifflin, New York. xvii + 606 pp., illus. U.S.$16.95.

*†**A natural history of western trees.** 1991. By Donald Culross Peattie. Re-issue of 1950 edition. xvi + 751 pp., illus. U.S.$18.95.

Plant defenses against mammalian herbivory. 1991. By R. Thomas Palo and Charles T. Robbins. CRC Press, Boca Raton, Florida. c192 pp. cU.S.$95 in U.S.A.; cU.S.$114 elsewhere.

*†**Vascular flora of the southeastern United States, volume 3, part 2: Leguminosae (Fabaceae).** 1990. By D. Isely. University of North Carolina Press, Chapel Hill. 258 pp. U.S.$35.

*†**Vascular plants of Minnesota: a checklist and atlas.** 1991. By Gerald B. Ownbey and Thomas Morley. University of Minnesota Press, Minneapolis. xi + 307 pp., illus. U.S.$39.95.

Environment

†**The balance of nature: ecological issues in the conservation of species and communities.** 1991. By Stuart L. Pimm. University of Chicago Press, Chicago. 464 pp., illus. Cloth U.S.$62; paper U.S.$26.95.

The biogeography of the British Isles: an introduction. 1990. By Peter Vincent. Routledge, New York. 336 pp., illus. U.S.$92.

†**The Colorado River through Grand Canyon: natura history and human change.** 1991. By Steven W. Carothers and Bryan T. Brown. University of Arizona press, Tucson. 320 pp., illus. Cloth U.S.$40; paper U.S.$17.95.

†**Ecology of desert communities.** 1991. Edited by Gary A. Polis. University of Arizona Press, Tucson. ix + 456 pp., illus. U.S.$49.95.

Environment in peril. 1991. Edited by Anthony B. Wolbarst. Smithsonian Institute Press, Washington. 272 pp., illus. U.S.$19.95.

Environmental policy and impact assessment in Japan. 1991. By Brendan D. Barrett and Biki Therivel. Routledge, New York. 256 pp., illus. U.S.$107.

*†**Foundations of ecology: classic papers with commentaries.** 1991. Edited by Leslie A. Real and James H. Brown. University of Chicago Press, Chicago. 1000 pp. Cloth U.S.$68.95; paper U.S.$24.95.

†**The fragile South pacific: an ecological odyssey.** 1991. By Andrew Mitchell. University of Texas Press, Austin. 280 pp., illus. U.S.$24.95.

Genetic and ecological diversity: the sport of nature. 1991. By Lawrence M. Hall. Chapman and Hall, New York. 208 pp., illus. U.S.$27.50.

Global climate change and life on earth. 1991. Edited by Richard Wyman. Chapman and Hall, New York. 288 pp. Cloth U.S.$55; paper U.S.$24.59.

†**The hidden coast: kayak explorations from Alaska to Mexico.** 1991. By Joel W. Roders. Alaska Northwest (GTE Discovery, Bothell, Washington). 168 pp., illus. U.S.$19.95; $24.95 in Canada.

Imperiled planet: restoring our endangered ecosystem. 1990. By Edward Goldsmith, et al. MIT Press, Cambridge. 288 pp., illus. U.S.$39.95.

†**A naturalist in New Guinea.** 1991. By Bruce M. Beehler. University of Texas Press, Austin. 251 pp., illus. U.S.$26.95.

One earth, one future: our changing global environment. 1990. By Cheryl Simon Silver. National Academy Press, Washington. xii + 196 pp., illus. U.S.$14.95.

Regreening the national parks. 1991. By Michael Frome. University of Arizona Press, Tucson. 250 pp. U.S.$29.95.

†**Tomorrow will be too late: east meets west on global ecology.** 1991. By Rolf Edberg and Alexel Yablokov. Translated by Sergei Chulaki. University of Arizona Press, Tucson. Cloth U.S.$29.95; paper U.S.$14.95.

Miscellaneous

*__Fossils: the key to the past.__ 1991. By Richard Fortey. Harvard, University Press, Cambridge. 187 pp., illus. U.S.$29.95.

The origins of natural science in America: the essays of Georghe Brown Goode. 1991. Edited by Sally Gregory Kohlstedt. Smithsonian Institute Press, Washington. 432 pp., illus. U.S.$45.

*__Pioneer ecologist: the life and work of Victor Rtmrdy Shelford 1877-1968.__ 1991. By Robert A. Croker. Smithsonian Institute Press, Washington. 288 pp., illus. U.S.$27.50.

Books for Young Naturalists

Amazing lizards. 1990. By Trevor Smith. Knopf, New York. 31 pp., illus. U.S.$6.95.

Animals that hibernate. 1991. By Larry Dane Brimner. Watts, New York. 64 pp., illus. U.S.$11.90.

Backyard hunter: the praying mantis. 1990. By Bianca Lavies. Dutton, New York. 32 pp., illus.

The big tree. 1991. By Bruce Hiscock. Atheneum, New York. 28 pp., illus. U.S.$13.95.

Chipmunk Song. 1990. By Joanne Ryder. Lodestar, New York. Illus. U.S.$3.95.

City science. 1991. By Peggy K. Perdue and Diane A. Vaszily. Good Year Gooks, Glenview, Illinois. 96 pp., illus. U.S.$9.95.

The complete handbook of science fair projects. 1991. By Julianne Blair Bochinski. Wiley, New York. xviii + 206 pp., illus. U.S.$12.95.

Coral reef. 1991. By Norman Barrett. Watts, New York. 32 pp., illus. U.S.$11.40.

Could you ever speak chimpanzee? 1990. By David J. Darling. Dillon, Minneapolis. 60 pp., illus. U.S.$14.95.

Eagles; Polar bears; Seals; Snakes. 1990. By Lucy Baker. Puffin, New York. Each: 32 pp., illus. U.S.$4.95.

Good planets are hard to find! 1990. By Roma Dehr and Ronald M. Bazar. Earth Beat Press, Vancouver. 39 pp., illus. $7.

Grey wolf, red wolf. 1990. By Dorothy Hinshaw Patent. Clarion Books, New York. 64 pp., illus. U.S.$15.95.

Harp seals. 1991. By Olga Cossi. Carolrhoda, Minneapolis. 48 pp., illus. U.S.$12.95.

Invertebrates: nature stories for children. 1990. By Barbara Batulla. Sterling, New York. 39 pp., illus. U.S.$4.95.

The kids' environment book: whats awry and why. 1991. By Anne Pedersen. John Muir, Santa Fe. 181 pp., illus. U.S.$13.95.

Life in the sea. 1991. By Jennifer Coldrey. Bookwright, New York. 32 pp., illus. U.S.$11.90.

Orca! the killer whale. 1990. By Sharon Lewis. Harper and Row, New York. 22 pp., illus. U.S.$8.95.

Questions answered by the New England Aquarium. 1991. By Les Kaufman and the staff of the New England Aquarium. Watts, New York. 40 pp., illus. U.S.$13.95.

Rads, ergs, and cheesebergers: the kid's guide to energy and the environment. 1991. By Bill Yanda. John Muir, Santa Fe. 96 pp., illus. U.S.$12.95.

Science brainstretchers: creative problem-solving activities in science, grades 4 - 6. 1991. By Anthony D. Fredericks. Good Year Books, Glenview, Illinois. 96 pp., illus. U.S.$9.95.

Sea otter rescue: the aftermath of an oil spill. 1990. By Roland Smith. Cobblehill (Dutton, New York). 64 pp., illus. U.S.$13.95.

The secretive timber rattlesnake. 1990. By Bianca Lavies. Dutton, New York. 32 pp., illus. U.S.$13.95.

Survival: could you be a mouse? Survival: could you be a frog? 1990. By John Norris Wood. Ideals, Nashville. Each: 28 pp., illus. U.S.$10.95.

Tiger! 1990. By Sharon Lewis. Harper and Row, New York. 22 pp., illus. U.S.$8.95.

The vanishing manatee. 1990. By Margaret Goff Clark. Cobblehill (Cutton, New York). 64 pp., illus. U.S.$13.95.

Why doesn't the sun burn out? and other not so dumb questions about energy. 1990. By Vicki Cobb. Lodestar, New York. 40 pp., illus. U.S.$13.95.

Winter; Spring. 1990. By Ron Hirshi. Cobblehill (Dutton, New York). Each: 23 pp., illus. U.S.$13.95.

Woodland trees. 1991. By Theresa Greenaway. Steck-Vaughn, Madison, New Jersey. 48 pp., illus. U.S.$15.96.

*Assigned for review
†Available for review

Advice to Contributors

Content

The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

Manuscripts

Please submit, **to the Editor,** in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

Type the manuscript on standard-size paper, if possible use paper with numbered lines, **double-space throughout**, leave generous margins to allow for copy marking, and **number each page**. For Articles and Notes provide a bibliographic strip, an abstract and a list of key words. Generally words should not be abbreviated but use SI symbols for units of measure. Underline only words meant to appear in italics. The names of authors of scientific names should be omitted except in taxonomic manuscripts or other papers involving nomenclatural problems. "Standard" common names (with initial letters capitalized) should be used at least once for all species of higher animals and plants; all should also be identified by scientific name.

The names of journals in the Literature Cited should be written out in full. Unpublished reports should not be cited here but placed in the text or in a separate documents section. Next list the captions for figures (numbered in arabic numerals and typed together on a separate page) and present the tables (each titled, numbered consecutively in arabic numerals, and placed on a separate page). Mark in the margin of the text the places for the figures and tables.

Extensive tabular or other supplementary material not essential to the text, typed neatly and headed by the title of the paper and the author's name and address, should be submitted in duplicate on letter-size paper for the Editor to place in the Depository of Unpublished Data, CISTI, National Research Council of Canada, Ottawa, Canada K1A 0S2. A notation in the published text should state that the material is available, at a nominal charge, from the Depository.

The **Council of Biology Editors Style Manual**, Fourth edition (1978) available from the American Institute of Biological Sciences, and **The Canadian Style: A Guide to Writing and Editing**, Department of the Secretary of State and Dundurn Press Ltd (1985) are recommended as general guides to contributors but check recent issues (particularly in literature cited) for exceptions in journal format. Either "British" or "American" spellings are acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary, Webster's New International Dictionary** and le **Grand Larousse Encyclopédique** are the authorities for spelling.

Illustrations

Photographs should have a glossy finish and show sharp contrasts. Photographic reproduction of line drawings, **no larger than a standard page**, are preferable to large originals. Prepare line drawings with India ink on good quality paper and letter (don't type) descriptive matter. Write author's name, title of paper, and figure number on the lower left corner or on the back of each illustration.

Reviewing Policy

Manuscripts submitted to *The Canadian Field-Naturalist* are normally sent for evaluation to an Associate Editor (who reviews it or asks another qualified person to do so), and at least one other reviewer, who is a specialist in the field, chosen by the Editor. Authors are encouraged to suggest names of suitable referees. Reviewers are asked to give a general appraisal of the manuscript followed by specific comments and constructive recommendations. Almost all manuscripts accepted for publication have undergone revision — sometimes extensive revision and reappraisal. **The Editor makes the final decision** on whether a manuscript is acceptable for publication, and in so doing aims to maintain the scientific quality, content, overall high standards and consistency of style, of the journal.

Special Charges — Please take special note

Authors **must share in the cost of publication** by paying $70 for each page in excess of five journal pages, plus $7 for each illustration (any size up to a full page), and up to $70 per page for tables (depending on size). Reproduction of color photos is extremely expensive; price quotations may be obtained from the Business Manager. Reprint order forms are included when galley proofs are sent to authors. If grant or institutional funds are available, we ask authors to defray a higher proportion of the cost of publishing, $70 per page for all published pages. Government institutions are expected to pay the full cost of publication. Authors must also be charged for their changes in proofs.

Limited journal funds are available to help offset publication charges to authors with minimal financial resources. Requests for financial assistance should be made to the Business Manager when the manuscript is accepted.

Reprints

An order form for the purchase of reprints will accompany the galley proofs sent to the authors.

FRANCIS R. COOK, Editor
RR 3 North Augusta, Ontario K0G 1R0

TABLE ON CONTENTS *(concluded)*

News and Comment

Notice of the 114th Meeting of The Ottawa Field-Naturalists' Club — Call for nominations: The Ottawa Field-Naturalists' Club 1993 Council — Call for nominations: The Ottawa Field-Naturalists' Club 1992 Awards — Errata: Canadian Field-Naturalist 105(4) 137

Minutes of the 113th Annual Business Meeting of The Ottawa Field-Natualists' Club: 11 February 1992 139

Revision of the Constitution and By-Laws of The Ottawa Field-Naturalists' Club 146

Book Reviews

Zooology: Birds of the Canadian Rockies — Anatomy of a Controversy: A Question of "Language" among Bees — Prairiewater: Watchable Wildlife at Beaverhills Lake, Alberta — Freshwater Macroinvertebrates of Northeastern North America — Neotropical Rainforest Mammals: A Field Guide — Interpretation and Explanation in the Study of Animal Behavior — Invertebrates — Pandas — Mammals of Oklahoma — Natural History of Seals —Protecting Internationally Important Bird Sites: A Review of the EEC Special Protection Area Network in Great Britain — Seabird Status and Conservation: A Supplement — Backyard Bird Song — The Biology and Evolution of Australian Lizards — Life History and Ecology of the Slider Turtle — Sharks, Sharks, Sharks — Sharkes and Whales 153

Botany: The Rare Vascular Plants of the Island of Newfoundland — Fungi on Plants and Plant Products in the United States — Discovering Wild Plants, Alaska, Western Canada, and the Northwest 165

Environment: Agroecology: Biological Resource Management — Ecological Diversity and its Measurement 167

Miscellaneous: Despite the Odds: Essays on Canadian Women and Science — Sacred Mountains of the World 168

Young Naturalists: Introducing Mammals to Young Naturalists — Invertebrates 170

New Titles 171

Advice to Contributors 174

Mailing date of the previous issue 105(4): 24 August 1992

Articles

Rare and endangered fishes and marine mammals in Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports VIII — R. R. CAMPBELL — 1

Status of the Northern Brook Lamprey, *Ichthyomyzon fossor*, in Canada — J. LANTEIGNE — 7

Status of the Chestnut Lamprey, *Ichthyomyzon castaneus*, in Canada — J. LANTEIGNE — 14

Status of the Y-Prickleback, *Allolumpenus hypochromus*, in Canada — R. E. CAMPBELL — 19

Status of the Pixie Poacher, *Occella impi*, in Canada — R. E. CAMPBELL — 24

Status of the Mountain Sucker, *Catostomus platyrhynchus*, in Canada — R. E. CAMPBELL — 27

Status of the Harbour Porpoise, *Phocoena phocoena*, in Canada — DAVID E. GASKIN — 36

Status of the Common Dolphin, *Delphinus delphis*, in Canada — DAVID E. GASKIN — 55

Status of the Atlantic White-sided Dolphin, *Lagenorhynchus acutus*, in Canada — DAVID E. GASKIN — 64

The extent, floristic composition and maintenance of the Rice Lake Plains, Ontario, based on historical records — P. M. CATLING, V. R. CATLING, and S. M. McKAY-KUJA — 73

Vascular plant flora of the Melville Hills Region, Northwest Territories — WILLIAM J. CODY, GEORGE W. SCOTTER, and STEVE C. ZOLTAI — 87

Bryophytes of the Melville Hills Region, Northwest Territories — GEORGE W. SCOTTER and DALE H. VITT — 100

Lichens of the Cape Parry and Melville Hills Regions, Northwest Territories — JOHN W. THOMSON and GEORGE W. SCOTTER — 105

Use of roadside salt licks by Moose, *Alces alces*, in northern New Hampshire — BRIAN K. MILLER and JOHN A. LITVAITIS — 112

Use of woody ground litter as a substrate for travel by the White-footed Mouse, *Peromyscus leucopus* — JOHN V. PLANZ and GORDON L. KIRKLAND, JR. — 118

Extended longevity in a large-bodied stickleback, *Gasterosteus,* population — T. E. REIMCHEN — 122

Notes

Two wolves, *Canis lupus*, killed by a Moose, *Alces alces*, in Jasper National Park, Alberta — J. L. WEAVER, C. ARVIDSON, and P. WOOD — 126

Brown Bear, *Ursus arctos middendorffi*, predation on a Trumpeter Swan, *Cygnus buccinator*, nest — PAUL HENSON and TODD A. GRANT — 128

Yellow-bellied Marmot, *Marmota flaviventris*, predation on Pikas, *Ochotona princeps* — JIM R. PETTERSON — 130

Two rare mosses from British Columbia — RICHARD D. REVEL — 132

White- and Pink-flowered *Cichorium intybus*, Blue-flowered Chicory, from British Columbia — RICHARD D. REVEL — 133

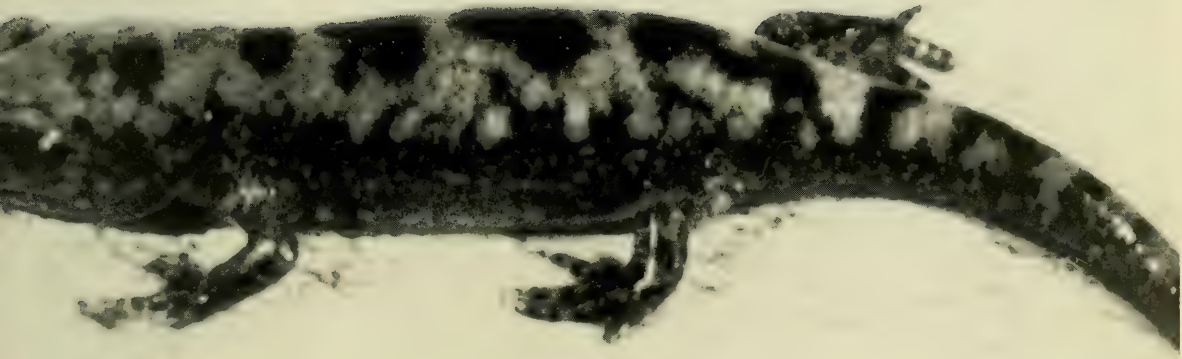
The relation between premolar wear and age in Yellow-bellied Marmots, *Marmota flaviventris* — DIRK VAN VUREN and CARMAN M. SALSBURY — 134

concluded on inside back cover

ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada



Volume 106, Number 2

April-June 1992

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency The Right Honourable Ramon John Hnatyshyn, P.C., C.C., C.M.M., Q.C.,
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Edward L. Bousfield
Irwin M. Brodo
William J. Cody
William G. Dore
R. Yorke Edwards
Anthony J. Erskine
Clarence Frankton
Claude E. Garton
W. Earl Godfrey
C. Stuart Houston
Louise de K. Lawrence
Thomas H. Manning
Don E. McAllister
Stewart D. MacDonald
Verna Ross McGiffin
Hue N. MacKenzie
Eugene G. Munroe
Robert W. Nero
Hugh M. Raup
Loris S. Russell
Douglas B.O. Savile
Pauline Snure
Mary E. Stuart
Sheila Thomson

1992 Council

President: Frank Pope
Vice-President: Michael Murphy
Recording Secretary: Connie Clark
Corresponding Secretary: Eileen Evans
Treasurer: Gillian Marston

Ronald E. Bedford
Barry Bendell
Fenja Brodo
Steve Blight
Lee Cairnie
Martha Camfield
William J. Cody
Francis R. Cook
Don Cuddy
Ellaine Dickson
Enid Frankton
Colin Gaskell
Bill Gummer
Jeff Harrison
Linda Maltby
Jack Romanow
Doreen Watler
Ken Young

Those wishing to communicate with the Club should address correspondence to: The Ottawa Field-Naturalists' Club, Box 3264, Postal Station C, Ottawa, Canada K1Y 4J5. For information on Club activities telephone (613) 722-3050.

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Editor: Francis R. Cook, R.R. 3, North Augusta, Ontario K0G 1R0; 613-269-3211
Assistant to Editor: P.J. Narraway; **Copy Editor:** Wanda J. Cook
Business Manager: William J. Cody, Box 3264, Postal Station C, Ottawa, Ontario K1Y 4J5 (613) 996-1665
Book Review Editor: Dr. J. Wilson Eedy, R.R. 1, Moffat, Ontario L0P 1J0
Coordinator, *The Biological Flora of Canada*: Dr. George H. La Roi, Department of Botany, University of Alberta, Edmonton, Alberta T6G 2E9
Associate Editors:

C.D. Bird
Robert R. Campbell
Brian W. Coad
Anthony J. Erskine
W. Earl Godfrey
Diana Laubitz
William O. Pruitt, Jr.
Stephen M. Smith

Chairman, Publications Committee: Ronald E. Bedford

All manuscripts intended for publication should be addressed to the Editor at home address.

Subscriptions and Membership
Subscription rates for individuals are $23 per calendar year. Libraries and other institutions may subscribe at the rate of $38 per year (volume). The Ottawa Field-Naturalists' Club annual membership fee of $23 includes a subscription to *The Canadian Field-Naturalist*. All foreign subscribers (including USA) must add an additional $4.00 to cover postage. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be mailed to: The Ottawa Field-Naturalists' Club, Box 3264, Postal Station C, Ottawa, Canada K1Y4J5.
Second Class Mail Registration No. 0527 – Return Postage Guaranteed. Date of this issue: April-June 1992 (May 1993).

Back Numbers and Index
Most back numbers of this journal and its predecessors, Transactions of The Ottawa Field-Naturalists' Club, 1879-1886, and The Ottawa Naturalist, 1887-1919, and Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: A newly transformed Marbled Salamander, *Ambystoma opacum*, collected as a larvae on Kelleys Island, Erie County, Ohio (41°36'N, 82°41'W), Photograph courtesy J. P. Bogart, University of Guelph, Guelph, Ontario. See article by L. A. Lowcock and J. P. Bogart, pages 196–199.

MCZ
LIBRARY
JUN 15 1993

The Canadian Field-Naturalist

Volume 106, Number 2 April–May 1992

HARVARD
UNIVERSITY

Arctic Cisco, *Coregonus autumnalis*, Distribution, Migration and Spawning in the Mackenzie River

ROBERT EARL DILLINGER, JR.[1,2], TIMOTHY P. BIRT[1], and JOHN M. GREEN[1,3]

[1]Department of Biology, Ocean Sciences Centre, Memorial University, St. John's, Newfoundland
[2]Idaho Department of Fish and Game, 1798 Trout Rd, Eagle, Idaho
[3]Author to whom reprint request should be sent.

Dillinger, Robert Earl, Jr., Timothy P. Birt, and John M. Green. 1992. Arctic Cisco, *Coregonus autumnalis*, distribution, migration and spawning in the Mackenzie River. Canadian Field-Naturalist 106(2): 175–180.

The distribution, migration, and spawning activities of Arctic Cisco (*Coregonus autumnalis*) in the tributaries of the Mackenzie River system were found to be more extensive than previously reported. The Peel River population had the earliest migration time, mid-July; however, a small movement of mature males upriver also occurred there in mid-September. Major movements of mature males and females took place in both late July and early to mid-September in the Arctic Red River. Migrations in the other river systems occurred in late August and early September. Arctic Ciscoes in the only river south of Great Bear Lake that has been found to contain this species, the Liard River, may show a mixed life history strategy. The apparently long distance the fish must swim, the lack of any known populations in any of the rivers between the Liard and Great Bear rivers, and the lack of evidence of migrations past Ft. Simpson suggest that this population may contain non-anadromous forms. No actual spawning was seen in any of the populations, but possible areas were noted, one in the Peel River and one in the Liard River.

Key Words: Arctic Cisco, *Coregonus autumnalis*, distribution, migration, spawning, Mackenzie River, Peel River, Arctic Red River, Liard River.

Oil exploration along the Beaufort Sea coast of North America has raised interest in populations of Arctic Cisco (*Coregonus autumnalis*) (Gallaway et al. 1983). In Alaska and Canada the Mackenzie River system has been identified as the source for the Arctic Cisco of the region (Gallaway et al. 1983; Bickham et al. 1989). In the early 1970s possible construction of the Mackenzie Valley pipeline initiated synoptic surveys of the Mackenzie River system (Hatfield et al. 1972*; Dryden et al. 1973*; Stein et al. 1973*). The rivers first identified as Arctic Cisco spawning rivers (Peel, Arctic Red, Great Bear and Liard) have received the most attention, although recent studies have investigated other tributaries (Sekerak 1989*). The presence of multiple stocks in this area, and the apparent long-distance of migrations undertaken, has led to increased study of the variation in observed traits as they relate to bet-hedging and other aspects of life history theory.

Here we present a synopsis of research on Arctic Cisco distributions and spawning activities in the Mackenzie River system undertaken by personnel from Memorial University of Newfoundland, LGL Ecological Research Associates, Inc, and LGL, Limited in the Mackenzie River region during the period 1985-1988.

Materials and Methods

All sampling was done in the Mackenzie River or its tributaries (Figure 1). Arctic Ciscoes were captured in 30 m long, 2½ m deep, 6 cm stretch mesh twine gill nets and a 10 m, 12.5 mm mesh bag seine. Nets were fished continuously during each sampling period. Previous studies (Hatfield et al. 1972*; Dryden et al. 1973*; Stein et al. 1973*) had used combinations of gill nets, angling, and seining.

Memorial University sampling took place in the fall of 1985 and summers of 1986 and 1987. Sampling by LGL personnel took place during the summer and fall of 1988. Reproductive condition was determined using egg size as a guide (Dillinger 1989).

*See Documents section; all other references in Literature Cited section.

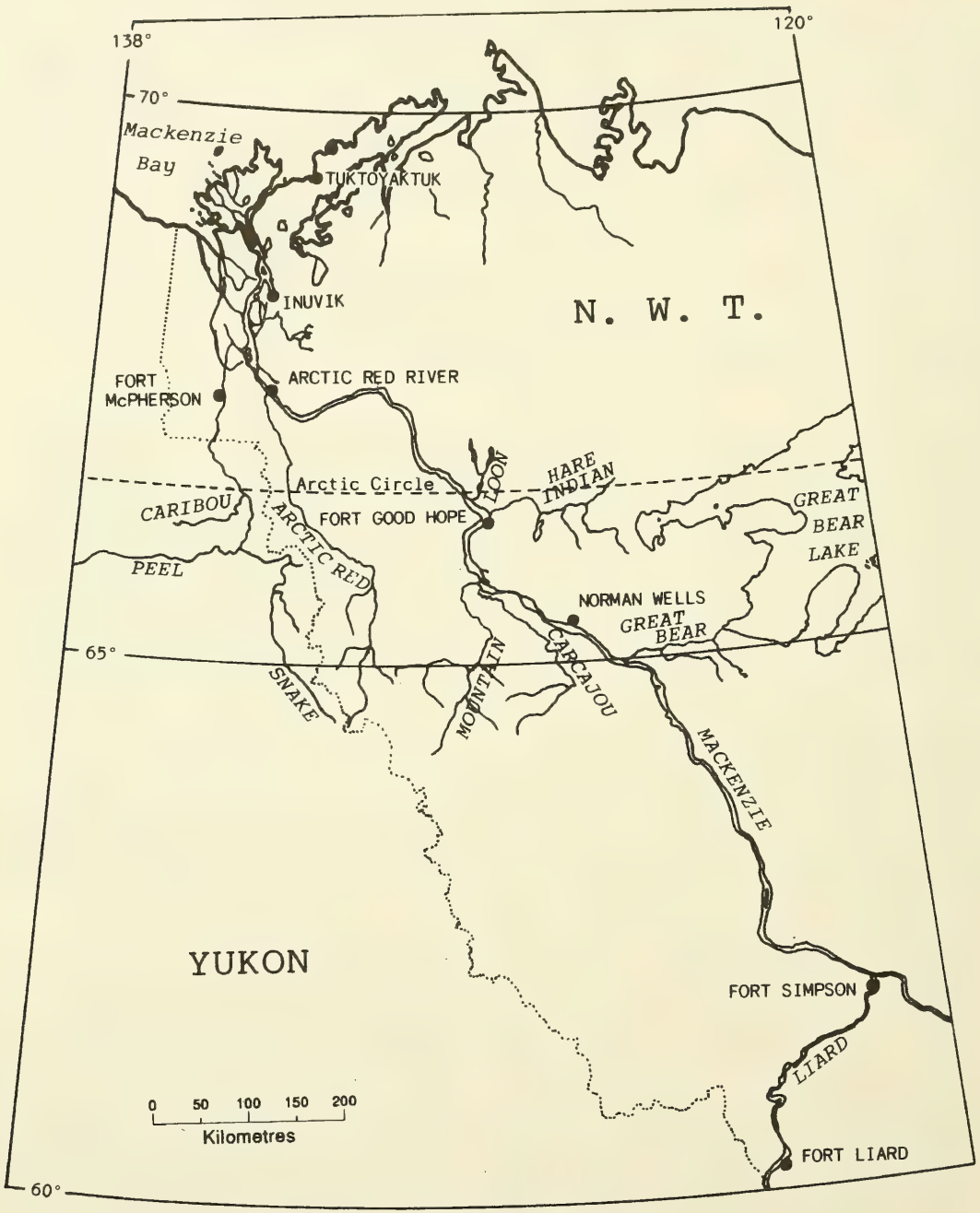


FIGURE 1. Mackenzie River and tributaries.

Results

Peel River

Catches were variable in all years, but the majority of the fish were caught in the lower Peel River in late July (Table 1). The exception was a young-of-the-year Arctic Cisco, approximately 65 mm in length, captured near the mouth of an unnamed tributary 31 km north of the Caribou River (Figure 2). This was the only small cisco captured in approximately 24 hours of seining activity.

TABLE 1. Samples of *Coregonus autumnalis* collected in the Peel River.

Location	Time	# Fish	Sex	Maturity
15 km upriver	7–9 September 1985	19	Male	All mature green
80–100 km upriver	7–9 September 1985	0		
1.60 km upriver	17–21 July 1986	22	3-Female; 18-Male; 1-Unknown	21 mature green
3–11 km upriver	18–25 July 1988	155		All mature

Arctic Red River

Catches here were also variable, with large numbers of fish taken in the lower portion of the river both early and late in the summer (Table 2). All fish captured were mature green (i.e. in spawning condition).

Mountain River

Seventy-five mature green Arctic Ciscoes were captured in the Mountain River, about 2–3 km from the mouth in multiple gill net sets, in late August 1933 (Figure 1).

Carcajou River

The Carcajou River was sampled in late August-early September 1988. A total of 20 mature Arctic Ciscoes (in spawning condition) were captured at a site 5 km from the river mouth (Figure 1).

Liard River

Sampling in 1988 took place near the town of Ft. Liard in mid-September. Thirty-nine mature, ripe Arctic Ciscoes were captured in two days (Figure 3).

Two other Mackenzie River tributaries, the Loon and Hare Indian rivers, were sampled in late August 1988 (Figure 1). No Arctic Ciscoes were captured in either river.

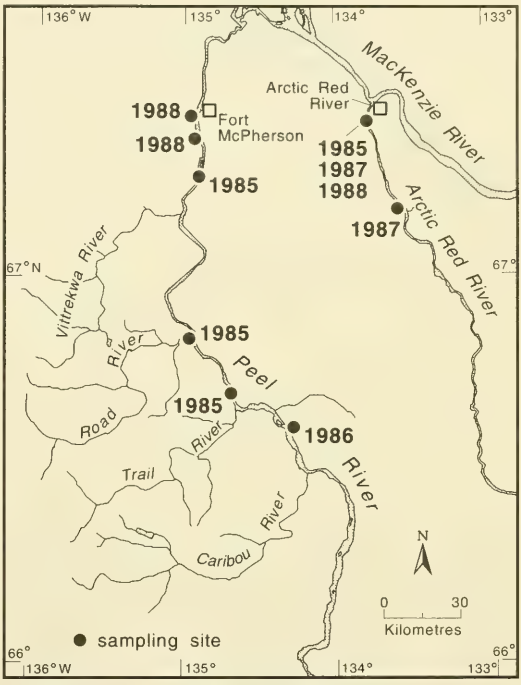


FIGURE 2. Lower Mackenzie River study area.

Discussion

Peel River

Based on the above catches, Arctic Cisco populations in the Mackenzie River system present what appears to be a mixed strategy for migration timing. In the Peel River, the largest proportion of the population appears to be early migrating, arriving in the hypothesized spawning area by mid-August in most years (D. Charley, personal communication 1985). Local residents who fish for Arctic Ciscoes report that the run begins in early to mid-July and ends by early August at the latest (J. Snowshoe, personal communication 1985; D. Charley, personal communication 1985; Rachel Ward, personal communication 1985; Dillinger, unpublished data). Local fishermen regard attempts to catch "herring" (a colloquial term for Arctic Ciscoes) in the lower sections of the river, near its mouth, after early August, as futile (John Snowshoe, personal communication 1985 Rachel Ward, personal communication 1985). This is early for an Arctic Cisco run, since at this time, fish in spawning condition can still be caught in the Phillips Bay region of the Yukon Territory (Dillinger 1989), but are not generally captured in the main stem of the Mackenzie until late August (Hatfield et al. 1972*; Dryden et al. 1973*; Stein et al. 1973*).

TABLE 2. Samples of *Coregonus autumnalis* collected in the Arctic Red River.

Location	Time	# Fish	Sex	Maturity
River mouth	9–13 September 1985	45	4-Female; 41-Male	All mature
80 km south	21–25 July 1987	12	5 Female; 7-Male	All mature
9 km south	28–30 July 1988	125		All mature

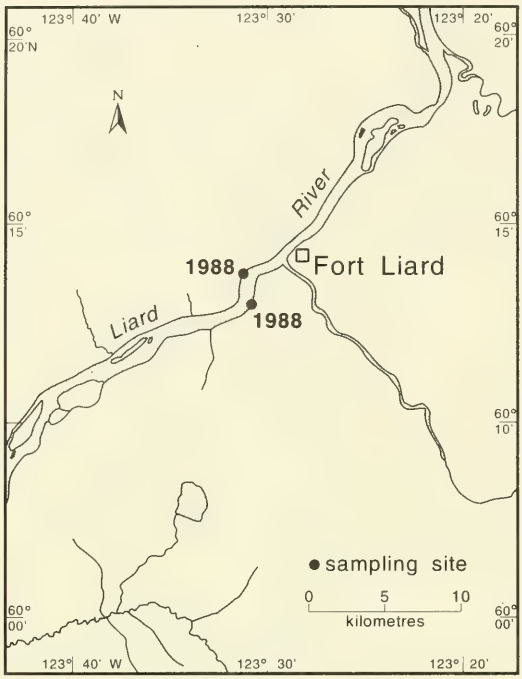


FIGURE 3. Liard River study area.

Mature males appear to continue to move upriver in small numbers through late September (Dillinger 1989), although the vast majority of fish have already proceeded well upriver and can be found in the region of the confluence of the Peel and Snake Rivers (D. Charley, personal communication 1985). These late-season smaller males probably do not contribute, to any appreciable extent, to the spawning population. The presence of these fish does suggest a different life history picture than that seen in the Arctic Red River.

Arctic Red River

The Arctic Red River stock has more variable run timing. This river may contain a "split" spawning run, two or more distinct, large pulses of upstream migrants. Hatfield et al. (1972*) reported fish in the river in late June 1971. Fish were captured 40 miles upriver in July 1987 and six miles upriver in July 1988 (Dillinger 1989, Sekerak 1989*). Males and females in spawning condition have also been captured at the mouth of the river in mid-September to early October (Nelson et al. 1987*; Dillinger 1989). Local residents who fish for "herring" look for them both at this time of the year, and in December when nets are set under the ice to catch them on their downstream migration (S. Lennie, personal communication 1985).

There are three possible explanations for these observations (1) the presence of two annual spawning runs or two distinct stocks, (2) a run which varies greatly among years in its timing, and (3) a run which extends throughout the summer. The third possibility appears unlikely based on the data collected by Hatfield et al. (1972*), and on sampling conducted near the mouth of the Arctic Red River in 1987 by Memorial University. The periods of time which passed during which no fish were caught in both of these studies suggest that this population does not have a single sharply defined run as is apparently seen in the Peel River or a run that continues through the summer. There are not enough data as yet to suggest that there is a single run that fluctuates through time. A more likely situation is the first one, that of different spawning times.

A population with two distinct run components separated in time results in the spreading of any risk associated with migration. The propensity of coregonines to migrate in groups and spawn in large aggregations (Nikolsky 1969) suggests that this is more effectively carried out by distinct run pulses, rather than a continuous, low-level movement upstream. Spawning would still be synchronous once the grounds were reached.

Distinct pulses of fish could also be the result of within-season temporal differences in maturation, which could be caused by environmental cues or genetic differences. The two runs could be made up of differentially maturing fish, such that first-time spawners may be the latest to run up the river having dispersed along the coast, while repeat spawners may have not ventured out of the tributary itself, or out of the influence of the Mackenzie River, and so do not have nearly as far to migrate.

Mountain, Carcajou, and Loon Rivers

Sampling by Hatfield et al. (1972*) and Dryden et al. (1973*) found no Arctic Ciscoes in either the Mountain or Loon rivers. Dryden et al. (1973*) reported a single immature Arctic Cisco in the Loon River in late June. The LGL sampling, which produced catches of apparently mature fish in both the Mountain and the Carcajou rivers, suggests that overwintering populations may be found in these rivers. Genetic research confirms the presence of a discrete spawning stock in each of the two rivers (Lockwood 1988; Morales et al. *in press*; Troy 1989*).

The lack of any Arctic Ciscoes being caught in the Loon River may have resulted from the timing of the sampling. If a small run used this river, it may have done so before or after the 10 September (1988) time of sampling. Water levels on this river during sampling were high, and flows were strong (S. Lockwood, personal communication 1988). It is also possible that the single fish taken by Dryden et al. (1973*) was misidentified. All three of these rivers appear to be suitable in both flow and topography to be used as overwintering or spawning habitat by Arctic Ciscoes (Hatfield et al. 1972*).

Great Bear River

This river was not sampled by either LGL or Memorial University personnel, but other observers have noted spawning runs in this river. Hatfield et al. (1972*) caught fish about 8 km upriver, McCart (1982*) found ripe males and females in the lower 12 miles of the river in late August, September and October. Nelson et al. (1987*) captured 73 mature, green Arctic Ciscoes in 43 hours of fishing in the Ft. Norman area in late August, late September and early October, 1985.

Liard River

The composition of the Liard River Arctic Cisco population is more puzzling and potential life history differences may be best resolved using genetic analysis, and morphometric comparisons. Catches from the Liard River, other than those of LGL in 1988, are generally confined to the Ft. Liard region, about 180-250 miles upstream from the mouth by McLeod et al. (1979*); O'Neil et al. (1982*); McLeod and O'Neil (1983). About thirty ripe Arctic Cisco were captured in a side channel of the Liard River, approximately 20 km upstream from the mouth (McLeod and O'Neil 1983). They speculated that this could be a spawning aggregation, but no spawned-out fish were collected.

Hatfield et al. (1972*) found few (8) Arctic Ciscoes in the Fort Simpson area, despite fishing all summer. Local residents are not aware of the presence of this fish, a situation similar to that seen in the Ft. Liard area (Sekerak 1989*). The Ft. Liard situation is probably due to the lack of fishing effort in that community (S. Douglas, personal communication 1985), while the cause in Ft. Simpson may be due to the use of large mesh nets which would not generally catch Arctic Ciscoes (K. Davidge, personal communication 1985). Those residents who are aware of Arctic Ciscoes say they rarely catch any, again probably due to the net mesh size (R. Norwegian, personal communication 1985). The presence of "ripe" fish in two locations distant from the mouth of the Mackenzie River, in spite of the extremely low numbers of fish caught in the area between Normal Wells and Ft. Simpson suggests the possibility of two different life history strategies (anadromous and non-anadromous) for Arctic Ciscoes in the Liard River.

The long distance to be traveled (over 2400 river kilometers), between the ocean and the suspected spawning areas, and the inability of the synoptic sampling to detect any populations between the Norman Wells region and Ft. Simpson (Hatfield et al. 1972*; Dryden et al. 1973*; Stein et al. 1973*) suggest that there could be a non-anadromous form of the Arctic Cisco in the Liard River. Sampling in the Ft. Simpson region, although somewhat sparse and sporadic in recent years, was extensive in the early 1970s and the small numbers of fish captured indicates that any anadromous component to this particular stock may have been small (Hatfield et al. 1972*; Dryden et al. 1973*; Stein et al. 1973*). A mixed strategy would be more stable than one incorporating a single life history form, if the latter contained no overwhelming advantage. An anadromous population migrating over these distances would appear to incur a severe disadvantage when compared to a non-anadromous form. The major advantage of anadromy, exposure to a larger food supply (Gross et al. 1988), could be negated by the expenditure of energy associated with migration, lack of feeding to replenish energy reserves, and increased mortality associated with a river migration of this length. Research on closely related forms (*C. sardinella*) along with the Yukon Coast has shown non-anadromous forms to be smaller and less fecund (Mann 1974*; Dillinger 1989), as is also the case when the non-anadromous Irish Pollan (*C. autumnalis*) is compared with anadromous Arctic Ciscoes (Dillinger 1989).

Spawning

The only indication of "known" spawning populations is anecdotal, but suggests that Arctic Ciscoes prefer a less turbid habitat for spawning. Residents of Ft. McPherson have seen large groups of Arctic Cisco in the Snake River region, a tributary of the Peel, in late fall, gathering over gravel substrate (D. Charley, personal communication 1985). This suggests (1) water clarity sufficient to observe the fish and (2) gravel substrate for spawning.

The other rivers in which populations of Arctic Ciscoes have been observed all have a fast flowing and/or mountainous component to them (Hatfield et al. 1972*; Dryden et al. 1973*). This may provide suitable spawning habitat, but these evaluations are somewhat suspect. Sekerak (1989*) observed that ice-up can produce considerably clearer conditions in turbid rivers, perhaps making what appears to be suboptimal habitat in summer into more desirable habitat in fall.

The presence of "ripe" fish in the lower Liard River, as well as the upper, suggests as well that there could be two or more spawning populations and/or locations. This would lend some credence to the hypothesis of a non-anadromous segment of the stock. Anecdotal reports of spawning ciscoes in Watson Lake in the late 1950s provide some support for this as well (D. Larson, personal communication 1987).

The most immediate research needs should focus on determining (1) if the smaller rivers surveyed support spawning populations that are stable through time, (2) the nature of run timing in the Arctic Red River, and (3) the life histories of the populations inhabiting the Liard River system.

Acknowledgments

We thank Teresa and Tim Green (Memorial University of Newfoundland), James Derr (Texas A&M University) and Samuel Lockwood (Texas A&M University) who assisted in collecting samples under trying circumstances. We also thank David Charley, John Snowshoe, Percy Kaye and Ken Roberts of Ft. McPherson, and Sam and Margie Lennie of Arctic Red River for their help and guidance over the course of the sampling effort. The 1986 and 1987 field seasons could not have been conducted without the logistic and moral support provided by John Ostrick and Moe McCrae of the Inuvik Science Research Laboratory, Inuvik, and William B. Griffiths of LGL Ltd, Sidney, British Columbia. G. Fain Hubbard drafted the initial figures. Funding for these studies was provided by BP Exploration Alaska and grants to J. M. Green from the Northern Science Training Program of the Canadian Department of Indian and Northern Affairs and the Natural Science and Engineering Research Council, Canada.

Literature Cited

(For unpublished reports, marked * in citations, see Documents section which follows Literature Cited).

Bickham, J. W., S. M. Carr, B. G. Hanks, D. W. Burton, and **B. J. Gallaway.** 1989. Genetic analysis of population variation in the Arctic cisco (*Coregonus autumnalis*) using electrophoretic, flow cytometric, and mitochondrial DNA restriction analyses. Biological Papers of the University of Alaska. Number 23: 112–122.

Dillinger, R. E., Jr. 1989. An analysis of the taxonomic status of the *Coregonus autumnalis* species complex in North America, and an investigation of the life histories of whitefishes and ciscoes (Pisces: Coregoninae) in North America and Eurasia. Ph.D. thesis. Memorial University of Newfoundland, St. John's, Newfoundland, Canada. 164 pages.

Gallaway, B. J., W. B. Griffiths, P. C. Craig, W. J. Gazey, and **J. W. Helmericks.** 1983. An assessment of the Colville River delta stock of Arctic cisco — migrants from Canada? Biological Papers of the University of Alaska Number 21: 4–23.

Gross, M. R., R. M. Coleman, and **R. M. McDowall.** 1988. Aquatic productivity and the evolution of diadromous fish migration. Science 239: 1291–1293.

Lockwood, S. F. 1989. Flow cytometric analysis of DNA content in spawning and coastal samples of Arctic cisco (*Coregonus autumnalis*). MSc thesis, Texas A&M University, College Station, Texas.

McLeod, C., and **J. O'Neil.** 1983. Major range extensions of anadromous salmonids and first record of chinook salmon in the Mackenzie River drainage. Canadian Journal of Zoology 61: 2183–2184.

Morales, J. C., J. W. Bickham, J. N. Derr, and **B. J. Gallaway.** *in press*. Genetic analysis of the population structure of Arctic cisco (*Coregonus autumnalis*) from the Beaufort Sea. Copeia.

Nikolsky, G. V. 1969. Fish Population Dynamics. Oliver and Boyd. Edinburgh, Scotland. 323 pages.

Documents

Dryden, R. L., B. G. Sutherland, and **J. N. Stein.** 1973. An evaluation of the fish resources of the Mackenzie River valley as related to pipeline development. Volume II. Environmental-Social Committee, Northern Pipelines, Task Force North Oil Development, Report 73-2. Ottawa, Ontario, Canada. 176 pages.

Hatfield, C. T., J. N. Stein, M. R. Falk, C. S. Jessop, and **D. N. Shepherd.** 1972. Fish resources of the Mackenzie River Valley. Environment Canada, Fisheries Service, Winnipeg, Manitoba, Canada. Interim Report. Volume 1, 247 pages; Volume 2, 289 pages.

Mann, G. J. 1974. Life history types of the least cisco (*Coregonus sardinella*) in the Yukon Territory, North Slope and eastern Mackenzie River delta drainages. Arctic Gas Biological Report Series 18(3). 160 pages.

McCart, D. 1982. An assessment of the fisheries resources of the Great Bear and Mackenzie Rivers in the vicinity of proposed IPL Pipeline crossings. Report Prepared by Aquatic Environments Ltd. for Interprovincial Pipeline (N.W.) Ltd, Vancouver, British Columbia, Canada. 33 pages plus figures and tables.

McLeod, C., J. O'Neil, L. Hildebrand, and **T. Clayton.** 1979. An examination of fish migrations in the Liard River, British Columbia, relative to proposed hydroelectric development at Site A. Report by RL&L Environmental Services Ltd., for B.C. Hydro and Power Authority, Vancouver, British Columbia, Canada. 176 pages.

Nelson, T., T. C. Cannon, W. R. Olmsted, and **K.C. Wiley.** 1987. Surveys of domestic and commercial fisheries in the central and eastern Beaufort Sea. 1985 Final Report, Volume 7, for Endicott Environmental Monitoring Program for U.S. Army Corps of Engineers, Anchorage, Alaska, U.S.A. 36 pages.

O'Neil, J., C. McLeod, L. Norton, L. Hildebrand, and **T. Clayton.** 1982. Aquatic investigations of the Liard River, British Columbia and Northwest Territories, relative to proposed hydroelectric development at Site A. Report by RL&L Environmental Services Ltd. for B.C. Hydro and Power Authority, Vancouver, British Columbia, Canada. 450 pages.

Sekerak, A. D. 1989. Known and suspected distribution of Arctic cisco (*Coregonus autumnalis*) in the MacKenzie River drainage. Unpublished manuscript. 22 pages.

Stein, J. N., C. S. Jessop, T. R. Porter, and **K. T. J. Chang-Kue.** 1973. An evaluation of the fish resources of the Mackenzie River valley as related to pipeline development. Volume 1. Environmental-Social Committee on Northern Pipelines, Task Force on Northern Oil Development, Report 73-1. Ottawa, Ontario, Canada. 121 pages.

Troy, D. M. 1989. Genetic analysis of population variation in the Arctic cisco using mitochondrial DNA restriction analyses. Chapter 5 *in* The 1988 Endicott Development Fish Monitoring Program: A Monograph of Project Papers, 1988. Report by LGL Alaska, Inc., for BP Exploration (Alaska) Inc., Anchorage, Alaska, U.S.A. 20 pages.

Received 8 February 1991
Accepted 8 February 1992

Home Range and Foraging Habitat of American Crows, *Corvus brachyrhynchos*, in a Waterfowl Breeding Area in Manitoba

BRIAN D. SULLIVAN[1,2] and JAMES J. DINSMORE[1]

[1]Department of Animal Ecology, 124 Science II, Iowa State University, Ames, Iowa 50011
[2]Present Address: Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744

Sullivan, Brian D., and James J. Dinsmore. 1992. Home range and foraging habitat of American Crows, *Corvus brachyrhynchos*, in a waterfowl breeding area in Manitoba. Canadian Field-Naturalist 106(2): 181–184.

American Crows were studied from April to July in 1986 and 1987 in southwestern Manitoba. Home ranges averaged 2.6 km^2. Foraging flights from the nest averaged 382 m; flights longer than 700 m were infrequent. American Crows used habitats for foraging in proportion to their occurrence within home ranges, but large individual variation existed. American Crows avoided tall vegetation while foraging, and seldom encountered duck nests.

Key Words: American Crow, *Corvus brachyrhynchos*, foraging, habitat use, home range, Manitoba, waterfowl.

Egg predation by American Crows (herein referred to as crows) long has been a concern of waterfowl managers (Kalmbach 1937; Johnson et al. 1989). An understanding of the home range size, flight distances, and foraging habitat of crows is fundamental to evaluating their importance as waterfowl nest predators. Current knowledge of crow foraging is limited to studies of food habits (Kalmbach 1937; Young 1989) and factors affecting egg predation (Sugden and Beyersbergen 1986, 1987; Sullivan and Dinsmore 1990). Only two authors have investigated the daily movements of crows during the breeding season (Schaefer 1983; Kilham 1989), and none has described crow use of foraging habitats quantitatively.

Our study was designed to (1) estimate the home range size of breeding crows, (2) measure flight distances from the nest, (3) assess foraging habitat use by crows, and (4) relate these parameters to potential interactions of crows with nesting waterfowl.

Study Area

The study was conducted from mid-April through mid-July in 1986 and 1987 on a 62 km^2 study area near Minnedosa in southwestern Manitoba (50°06'N; 99°50'W). Lying within the aspen (*Populus* spp.) parklands of the prairie pothole region, this area is characterized by uplands that are intensively cultivated and interspersed with numerous wetland basins that support a high density of breeding waterfowl (Smith et al. 1964; Stoudt 1982). Gravel roads bound most sections (2.59 km^2) of land. Ducks nested primarily in narrow strips of vegetation along wetland basins or roadsides, whereas crows nested in farm shelterbelts, willow (*Salix* spp.) shrubs near wetlands, or in small, aspen-dominated woodlots. Stoudt (1982) provided a detailed description of the natural history of the Minnedosa area.

Methods

Crow nests were located by searching woody vegetation in areas where crows were observed. In 1987, two adult male crows were captured and fitted with radio transmitters.

Radio-marked crows were monitored from a vehicle; line-of-sight accuracy of the receiving system was tested daily. When locating individual crows, bearings were taken from three different positions in rapid succession and plotted on maps. Radio locations often were confirmed visually. We located each radio-marked crow two or three times per day at intervals of at least several hours. Telemetry also was conducted periodically on two nights to determine if movement occurred during darkness.

Home range and flight distance information was collected by tracking crows visually in 1986 and by a combination of visual tracking and radiotelemetry in 1987. Because of the fine interspersion of habitat types on the study area and the observation that crows often foraged along habitat edges, we believed that even small errors in determining locations of radio-marked crows would be unacceptable for assessing habitat use. Therefore, we relied solely on visual observations for collecting foraging habitat data.

Foraging observations were conducted from vehicles because crows become accustomed quickly to their presence and continued foraging undisturbed. Each day was divided into three equal periods (morning, midday, and evening) based on available daylight hours, and observations of each pair were balanced among these periods. We followed foraging crows continuously during 1-h observation sessions using binoculars or a telescope. Crows usually foraged singly, but if the pair foraged together we used data for only one bird to ensure independence. Pairs usually were observed two times per day for a

total of two hours. The amount of time spent foraging in each habitat type (cropland, wetland [including narrow upland perimeters], or miscellaneous [roadsides (including ditches), pastures, farmyards, farm lanes, fencerows, railroad rights-of-way, and woodland]) was recorded with a stopwatch. All flight paths and foraging locations were plotted on maps. The maximum straight-line distance from the nest attained on each flight was measured from aerial photographs (scale = 1:16 000). We ceased observing pairs after the young crows began to accompany the adults on extended flights, because at that time the crows gradually began to abandon their breeding home ranges.

All known locations (determined from foraging observations, radiotelemetry, chance sightings, or during nest inspections) were combined for each pair. Home range boundaries were determined by the minimum convex polygon method (Mohr 1947) and plotted on aerial photographs. Home range areas were measured with a planimeter. We used Pearson's correlation coefficient to determine if our estimates of home range areas were influenced by the amount of time that we observed the birds.

Habitat composition of each home range was estimated by overlaying the aerial photographs with a fine dot grid (3-mm dot spacing) and classifying the habitat beneath each point into categories as described previously. We sampled an average of 1372 points per home range. At this sampling intensity, the occurrence of all habitats in each home range could be estimated to within 3% of the true proportions with 95% confidence (Thompson 1987).

For each pair of crows, the proportion of the total foraging time spent in each habitat was compared to the proportional occurrence of the habitats within the pair's home range (Design 3 of Thomas and Taylor 1990). We used Friedman's nonparametric test (Friedman 1937, as described in Conover 1980) to test the null hypothesis that the ranks of the differences in use and occurrence were the same for all habitats (Alldredge and Ratti 1986, 1992). Based on study design, sample sizes, hypothesis tests, assumptions, and methods of calculation, we felt that Friedman's test was more appropriate than other statistical tests of resource selection (Alldredge and Ratti 1986, 1992; Thomas and Taylor 1990). Statistical significance was established at $P \leq 0.05$ for all tests.

Results

Flight distances, complete breeding season home ranges, and foraging habitat information were collected on 22, 10, and nine pairs of crows, respectively. Home ranges were estimated from visual observations for eight pairs (mean number of 1-h observation sessions = 37, range = 20–64), by radiotelemetry for one pair (59 telemetry relocations), and by a combination of the two methods for one pair (43 1-h observation sessions, 63 telemetry relocations).

TABLE 1. Flight distances from the nest ($n = 404$) for breeding American Crows in southwestern Manitoba, Canada, 1986–1987.

Distance category	Proportion of flights in each category (cumulative proportion in parentheses)
0–350 m	0.57 (0.57)
351–700 m	0.30 (0.87)
701–1000 m	0.08 (0.95)
> 1000 m	0.05 (1.00)

Crows occupied non-overlapping home ranges that averaged 2.6 km^2 (SD = 1.4, range 0.8–6.0 km^2, $n = 10$). There was no significant correlation between home range area and the number of 1-h observation sessions ($r = 0.53$, $P = 0.14$, $n = 9$). Although our sample size was small, this may suggest that our observation effort was sufficient to estimate home range areas adequately.

The mean foraging flight distance was 382 m (SD = 318, range = 16–2078 m, $n = 404$). Crows seldom made extended flights from their nests; flights longer than 700 m were infrequent, and they rarely exceeded 1000 m (Table 1). Crows did not leave their evening roost site (always near the nest) during night telemetry surveillance.

Crows foraged most often in cropland, but cropland was the only habitat used in lower proportion than it occurred within home ranges (Table 2). Miscellaneous habitats were used by foraging crows twice as much as these habitats occurred; wetland habitat was used slightly more than its occurrence (Table 2). The Friedman test was not significant ($T_2 = 1.53$, $0.10 < P < 0.25$, DF = 2, 16), indicating overall proportional use of foraging habitats by the crow pairs under study. However, individual crow pairs showed highly variable use of foraging habitats. Some pairs used a particular habitat extensively, while other pairs made little use of the same habitat.

We did not observe crows foraging in wooded areas, so we recomputed the proportional occurrence

TABLE 2. Mean proportion of use and occurrence within home ranges of foraging habitats for nine pairs of American Crows in southwestern Manitoba, Canada, 1986–1987.

Habitat type[a]	Mean Use (SD)	Mean Occurrence (SD)
Cropland	0.57 (0.18)	0.70 (0.04)
Wetland	0.29 (0.19)	0.23 (0.04)
Miscellaneous	0.14 (0.15)	0.07 (0.01)

[a] See text for definition.

of the three habitat categories excluding woodland. Habitat rankings were not affected for any crow pair, thus precluding any effect on the statistical procedure.

Although it was not studied directly, our observations indicated that vegetation height had a major influence on where crows foraged. Crows ceased foraging in seeded cropland when the vegetation height exceeded their own, at which time they made greater use of barren fallow fields. Crows made greatest use of roadsides late in the nesting season when vegetation in other habitats was tall and dense. Low, heavily grazed pastures were present in the home ranges of two crow pairs, and both pairs foraged extensively in this habitat. Three pairs that made greatest use of wetland habitats most often foraged in one or two wetlands where the perimeter vegetation remained low due to haying or cultivation.

During > 400 h of observation, we saw only one instance where a crow flushed a female duck (a Northern Shoveler, *Anas clypeata*) from a nest and consumed the eggs. Crows were observed at only three other duck nests, all of which had been abandoned or previously depredated by another predator. In no other instances were crows seen transporting or feeding on duck eggs.

Discussion

The mean breeding season home range area of crows in our study was 70% larger than for seven crow pairs in Iowa (Schaefer 1983) and nearly 300% larger than the largest territories of several groups of cooperatively breeding crows in Florida (Kilham 1989: 40).

The analysis of flight distances complements our findings in a related study (Sullivan and Dinsmore 1990) in which rates of crow predation on artificial duck nests decreased markedly at distances greater than 700 m from crow nests. The longest flight from a nest reported by Schaefer (1983) was 4.8 km, compared to only 2.1 km in our study.

There was no indication that crows used foraging habitats that would lead them to frequent contact with nesting waterfowl. Crows spent 57% of their foraging time in cropland; this habitat supports low densities of duck nests (Cowardin et al. 1985; Klett et al. 1988). In wetland and miscellaneous habitats, crows were attracted to areas disturbed by farm machinery or livestock; these areas would not have been conducive to successful hatching of duck nests regardless of the presence of crows. The apparent avoidance of taller vegetation by crows may reduce encounters with duck nests. Kilham (1989: 115) noted that crows stopped foraging in hayfields when the vegetation grew tall, but returned after it had been cut. Sugden and Beyersbergen (1987) found that crow predation on concealed artificial nests in tall vegetation was less frequent than in short vegetation for crows foraging on foot. They postulated that tall, dense cover served as a behavioral deterrent and physical barrier to crows hunting on foot, and we concur. However, we found previously that when crows had located a nest through aerial searching, increased vegetation height above 20–50 cm did not reduce predation on the eggs (Sullivan and Dinsmore 1990).

Although we specifically watched for crow predation on duck nests, we observed few such encounters. In previous waterfowl nesting studies, crows may have been blamed for nests initially depredated by other predator species. Investigator disturbance of nests also can bias rates of crow predation upward (Salathé 1987). Although crows depredate some duck nests, their relative importance as a duck nest predator may be less than previously suggested.

Acknowledgments

This project was funded by the North American Wildlife Foundation (through the Delta Waterfowl and Wetlands Research Station) and Iowa State University (through the Department of Animal Ecology, the Iowa Cooperative Fish and Wildlife Research Unit, and the Iowa Agriculture and Home Economics Experiment Station). We thank J. Buenger, B. Feë, M. Gloutney, W. Hester, R. Keith, K. Maguire, and D. Richardson for assistance in collecting data, and A. J. Erskine, D. Glenn-Lewin, E. Klaas, and L. Sugden for providing critical comments on the manuscript. M. Anderson, A. Sargeant, J. Schaefer, and L. Sugden provided valuable insight during the formative stages of the study. This is Journal Paper J-13145 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa, Project Number 2466.

Literature Cited

Alldredge, J. R., and **J. T. Ratti.** 1986. Comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management 50: 157–165.

Alldredge, J. R., and **J. T. Ratti.** 1992. Further comparison of some statistical techniques for analysis of resource selection. Journal of Wildlife Management 56: 1–9.

Conover, W. J. 1980. Practical nonparametric statistics. Second edition. John Wiley and Sons, New York. 493 pages.

Cowardin, L. M., D. S. Gilmer, and **C. W. Shaiffer.** 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildlife Monographs 92: 1–37.

Friedman, M. 1937. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. Journal of the American Statistical Association 32: 675–701.

Johnson, D. H., A. B. Sargeant, and **R. J. Greenwood.** 1989. Importance of individual species of predators on nesting success of ducks in the Canadian Prairie Pothole Region. Canadian Journal of Zoology 67: 291–297.

Kalmbach, E. R. 1937. Crow-waterfowl relationships based on preliminary studies on Canadian breeding grounds. United States Department of Agriculture Circular Number 433. 35 pages.

Kilham, L. 1989. The American Crow and the Common Raven. Texas A & M University Press, College Station. 255 pages.

Klett, A. T., T. L. Shafer, and **D. H. Johnson.** 1988. Duck nest success in the prairie pothole region. Journal of Wildlife Management 52: 431–440.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37: 233–249.

Salathé, T. 1987. Crow predation on coot eggs: effects of investigator disturbance, nest cover and predator learning. Ardea 75: 221–229.

Schaefer, J. M. 1983. The Common Crow as a sentinel species of rabies in wildlife populations. Ph.D. dissertation, Iowa State University, Ames. 81 pages.

Smith, A. G., J. H. Stoudt, and **J. B. Gollop.** 1964. Prairie potholes and marshes. Pages 39–50 *in* Waterfowl Tomorrow. *Edited by* J. P. Linduska. United States Fish and Wildlife Service, United States Government Printing Office, Washington, DC.

Stoudt, J. H. 1982. Habitat use and productivity of canvasbacks in southwestern Manitoba, 1961–72. United States Fish and Wildlife Service Special Scientific Report, Wildlife Number 248. 31 pages.

Sugden, L. G., and **G. W. Beyersbergen.** 1986. Effect of density and concealment on American Crow predation of simulated duck nests. Journal of Wildlife Management 50: 9–14.

Sugden, L. G., and **G. W. Beyersbergen.** 1987. Effect of nesting cover density on American Crow predation of simulated duck nests. Journal of Wildlife Management 51: 481–485.

Sullivan, B. D., and **J. J. Dinsmore.** 1990. Factors affecting egg predation by American Crows. Journal of Wildlife Management 54: 433–437.

Thomas, D. L., and **E. J. Taylor.** 1990. Study designs and tests for comparing resource use and availability. Journal of Wildlife Management 54: 322–330.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41: 42–46.

Young, A. D. 1989. Body composition and diet of breeding female Common Crows. Condor 91: 671–674.

Received 29 May 1990
Accepted 10 April 1992

Effects of Aspen Succession on Sharp-tailed Grouse, *Tympanuchus phasianellus*, in the Interlake Region of Manitoba

ROBERT P. BERGER and RICHARD K. BAYDACK

Natural Resources Institute, University of Manitoba, Winnipeg, Manitoba R3T 2N2

Berger, Robert P. and Richard K. Baydack. 1992. Effects of aspen succession on Sharp-tailed Grouse, *Tympanuchus phasianellus*, in the Interlake Region of Manitoba. Canadian Field-Naturalist 106(2): 185–191.

Habitat around 12 leks of prairie Sharp-tailed Grouse (*Tympanuchus phasianellus campestris*) in Manitoba was examined. Analysis of 21 years (1965 to 1986) of aerial photographs revealed that 36% of the area within 1 km of leks changed from prairie to closed aspen forest. Seven of 12 study leks were abandoned during this period, three remained active, and two new leks became active. In 1976, at least 12 leks existed within the study area, but by 1986 only five remained. Leks were abandoned when aspen forest increased beyond 56% and prairie fell below 15% of the total area within 1 km of the lek. A reduction in the population of Sharp-tailed Grouse on the study area appeared to be associated with loss of prairie habitat. A model associating lek abandonment and prairie cover values was developed to be used as a management tool.

Key Words: Sharp-tailed Grouse, *Tympanuchus phasianellus*, habitat, lek, dancing ground, Manitoba, Trembling Aspen, *Populus tremuloides*, succession, prairie management.

The prairie Sharp-tailed Grouse, *Tympanuchus phasianellus campestris*, is found in the aspen parkland of North America. The ratio of aspen to prairie was maintained historically by wildfires (DeByle and Winokur 1985), since over time, without fire aspen begins to dominate the community. Sharp-tailed Grouse disappeared from areas in Michigan as a result of this succession (Ammann 1963). Hamerstrom et al. (1961) suggested that natural forest succession decreases the range of Sharp-tailed Grouse throughout North America.

Sharp-tailed Grouse use areas of grass, shrub, and forest for breeding, nesting, brooding, feeding, loafing, and for escaping predators (Evans 1968; Sexton 1979; Moyles 1981). Aspen dominated areas are used primarily in winter, for cover, roosting and as a food source (Evans 1968; Sexton 1979; Gratson 1988). Leks are open grassland sites with low or sparse vegetation, usually slightly elevated above surrounding land. Unhindered visibility, nearby (<500 m) escape cover and nearby female perching sites are also associated with these locations in spring (Pepper 1972; Sisson 1976; Baydack 1988).

Using these past findings, we designed a study to assess the effects of succession on the use of habitat by Sharp-tailed Grouse. Aerial photographic data and records of Sharp-tailed Grouse use of specific sites were available for a 21-year period, 1965 to 1986. We looked at the change in composition of aspen parkland and documented Sharp-tailed Grouse response.

Study Area and Methods

This study was carried out in a 20 km^2 area of aspen parkland in the Narcisse Wildlife Management Area (NWMA), 50°47'N, 97°34'W, approximately 100 km N of Winnipeg, in the Interlake region of Manitoba (Figure 1). The land is a relatively flat to gently undulating glacial till plain. Soil cover is generally thin, stony, and high in lime. Soil types are classified as gray wooded, dark gray, peaty meadow, or half-bog soils (Pratt et al. 1961).

The dominant tree species is Trembling Aspen. Common shrubs include roses (*Rosa* spp.), Saskatoon (*Amelanchier alnifolia*), Western Snowberry (*Symphoricarpos occidentalis*), and Dwarf Birch (*Betula glandulosa*). Common forbs and grasses include Bearberry (*Arctostaphylos uva-ursi*), Common Bedstraw (*Galium boreale*), asters (*Aster* spp.), needlegrasses (*Stipa* spp.), wheatgrasses (*Agropyron* spp.), and wild rye (*Elymus canadensis*). (Rusch et al. 1978; Dixon 1979; Sexton 1979; Berger 1989).

Fires which occurred throughout the study area prior to 1967 maintained a prairie habitat relatively free of aspen. Fire was suppressed after 1967, but burns occasionally occurred. Yearly fire reports for NWMA were used to determine areas of recent burns.

Vegetation patterns were determined in the NWMA from 1965 to 1986 from color and black and white aerial photographs obtained from the Manitoba Remote Sensing Center. Photographic scale in 1965, 1975, and 1981 ranged from 1: 8 000 to 1: 15 000; autumn 1986 and 1987 photographs were 1: 14 000.

Areas for vegetation mapping were selected based on current and historical occurrences of Sharp-tailed Grouse within specific blocks of habitat. A 1.0 km radius surrounding each lek was designated for interpretation and mapping, based on Sharp-tailed Grouse preference for habitat immediately surrounding leks (Caldwell 1976; Moyles 1981).

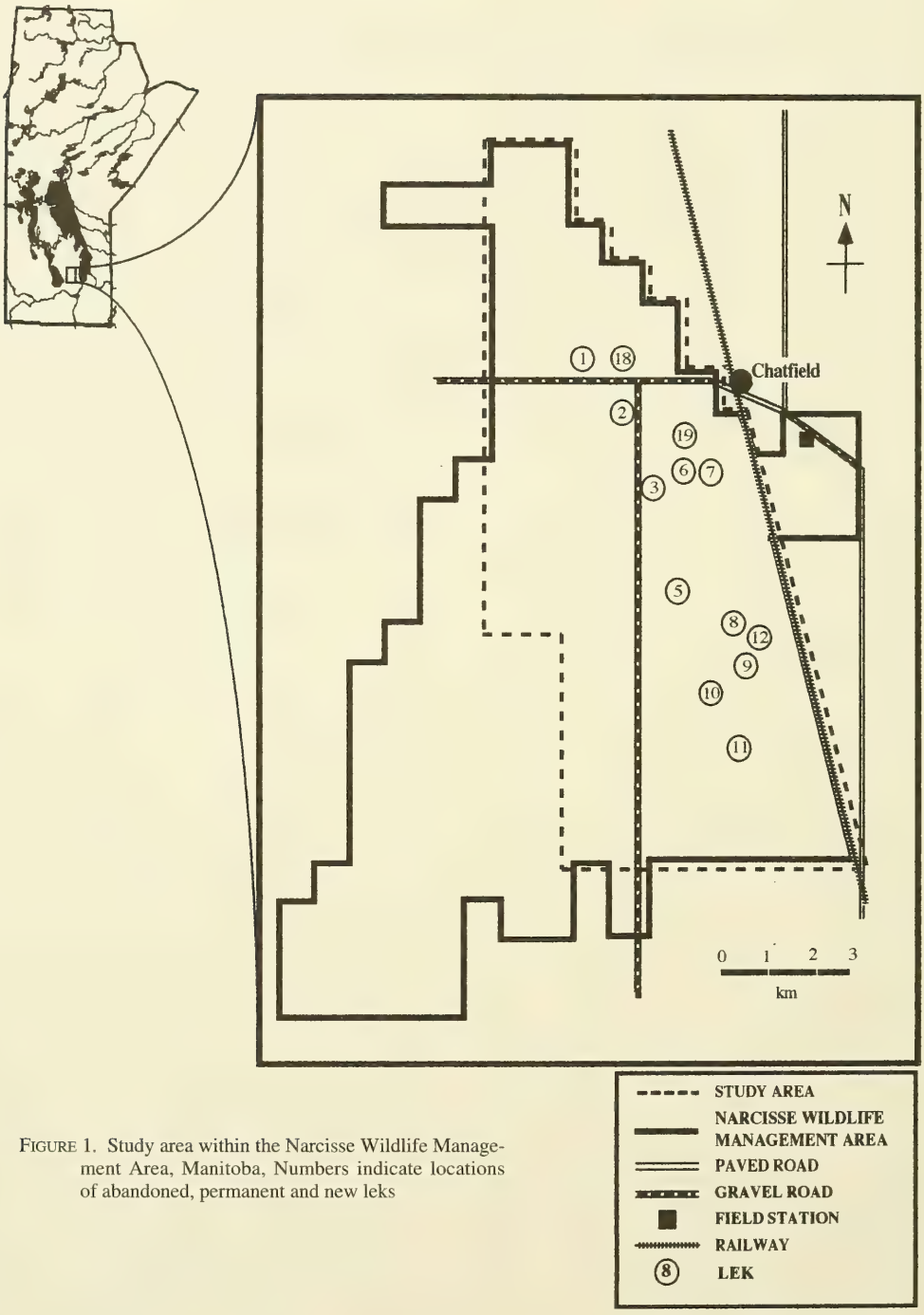


FIGURE 1. Study area within the Narcisse Wildlife Management Area, Manitoba, Numbers indicate locations of abandoned, permanent and new leks

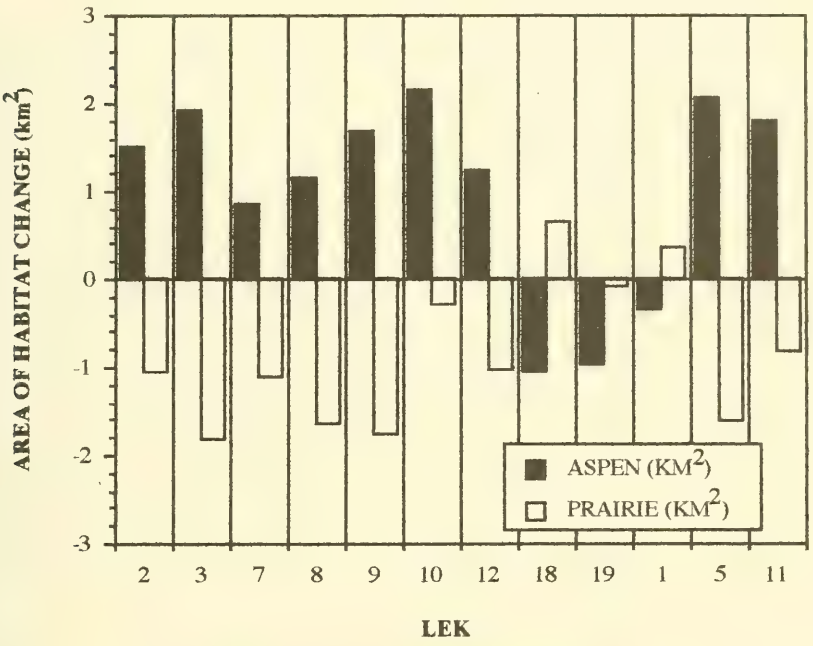


FIGURE 2. Lek status and habitat change (1970–1986) in the Narcisse Wildlife Area, Manitoba

Aerial photographs were interpreted and mapped with a Bausch and Lomb Zoom Transfer Scope. Using a numerical vegetation classification system (Sexton and Dixon 1978), habitat types were labelled, boundaries were delineated, and the map transferred to mylar. The total area under investigation at each lek equalled 3.14 km^2. Vegetation patterns surrounding 12 lek locations were analyzed over the 21 year mapping period.

Areas were measured with a Calcomp 9100 Digitizer. The scale of each map was measured and set using the scale bar method. The total area of each habitat type was determined and its percentage cover calculated (Estes and Thorley 1983).

Sources of error from photographic interpretation and measurement were estimated as follows. Samples of five different areas were drawn independently of one another, each area having a similar shape and size. These five samples were pooled, and error expressed as percent error or as ± km^2. Pooled

TABLE 1. Distribution of habitat types in the Narcisse Wildlife Management Area, Manitoba, from 1965-1986.

Cover type	Abandoned Leks	Leks Prior to Abandonment	Permanent Leks	Average Change on All Leks
Aspen Closed Forest	56%	43%	44%	36.2%
Aspen Open Forest	14%	12%	15%	2.5%
Prairie and Abandoned Fields	15%	28%	23%	(-) 37.5%
Shrub	12%	15%	17%	2.3%
Marsh	3%	2%	1%	(-) 1.1%

variance was used to estimate the standard error used for the habitat analysis. Paired *t*-tests were used to assess habitat change between years. Habitat cover values derived from two independent interpretations in the same sampling year were compared between years using *t*-tests with one degree of freedom. Habitat change was calculated between 1965 and 1986, or 1975 and 1986 unless otherwise stated.

The number of Sharp-tailed Grouse on leks was determined from historical records by selecting the maximum number of males attending each season, as per Cannon and Knopf (1981). Counts of the total number of leks in the study area were made and plotted along with the percent habitat cover values. The relationship between grouse numbers and habitat availability was examined graphically.

Results

Over the 21 years of available data, at least 12 leks were active for varying periods of time. Leks were categorized as abandoned, recently established, or permanent.

Habitat change

Seven of the leks (2, 3, 7, 8, 9, 10, and 12) were abandoned between 1976 and 1986. In 1975, of the 3.14 km^2 around each lek, prairie occupied an average area of 0.8 km^2 while closed aspen forest averaged 1.3 km^2. By 1986, prairie had been reduced to an average of 0.2 km^2 while aspen had increased to 2.0 km^2 (Figure 2). Six of the seven leks showed an increase ($P < 0.1$) in aspen and a decrease ($P < 0.1$) in prairie. Standard error in mapping was calculated as ± 0.35 km^2 or 11.2% for all habitat types considered on each map.

Between 1965 and 1986, closed aspen forest increased an average of 36.2% in total area, open aspen forest increased 2.5%, prairie declined 37.5%, shrubs increased 2.3% and marsh decreased by 1.1%. The average cover of habitat types surrounding leks is presented in Table 1.

Leks 18 and 19 were established between 1978 and 1985. In 1975, prairie occupied an average of 0.5 km^2 surrounding these leks while closed aspen forest averaged 1.9 km^2. By 1986, prairie increased to 0.8 km^2 while aspen decreased to 0.8 km^2. This increase could be explained by fires, which burned over lek 18 in 1975, 1976 and 1981, and lek 19 in 1980. Both areas had decreased ($P < 0.1$) aspen cover surrounding the leks, but only lek 18 showed an increase ($P < 0.1$) in the amount of prairie.

Three leks (1, 5 and 11) were permanent from 1971 to 1986. Leks 1 and 5 occurred on prairie-like areas (old agricultural fields). Aspen forest and prairie cover remained unaltered surrounding lek 1 ($P > 0.1$), while aspen forest increased and prairie decreased in the vicinity of leks 5 ($P < 0.05$) and 11 ($P < 0.1$).

Rate of vegetation change

Taking the approximate average habitat change for all leks between 1965 and 1986, aspen increased by an average rate of 1.8% per year, while prairie decreased by an average rate of 1.8% per year. Around the seven abandoned leks, aspen increased at an average 0.06 km^2 per year. Prairie declined at 0.06 km^2 per year. Around the five leks which remained between 1970 and 1986, three showed aspen decrease at 0.15 km^2 per year and prairie increase at 0.1 km^2 per year. Around the two remain-

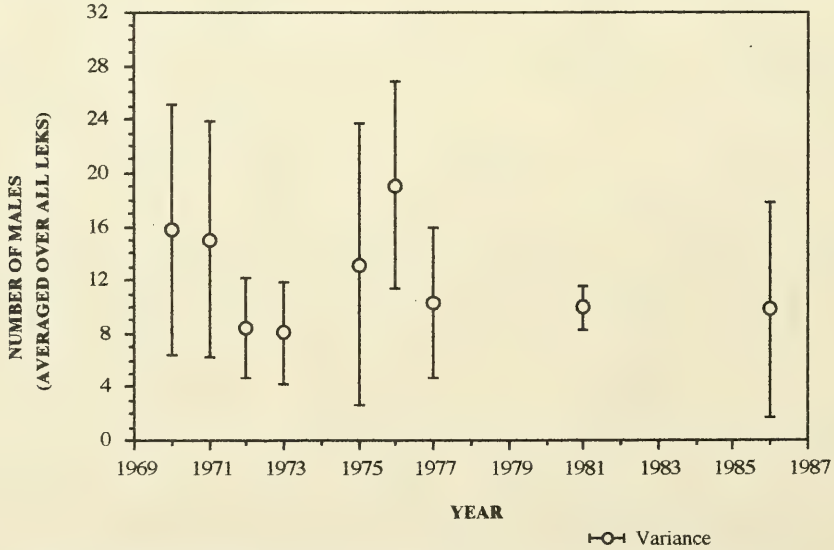


FIGURE 3. Average number of Sharp-tailed Grouse per lek in the Narcisse Wildlife Area, Manitoba, from 1970–1986.

ing leks, aspen increased at a mean rate of 0.35 km^2 and prairie decreased at a rate of 0.24 km^2 per year. These two leks remained stable since 1970 and 1971 respectively.

Change in number of grouse

The mean number of Sharp-tailed Grouse on all leks was calculated by taking the total number of grouse on all leks during a single year and dividing it by the number of active leks (>2 grouse/lek) in that year. There is no apparent increase or decrease in the mean number of grouse per lek between 1970 and 1986 (Figure 3). The total number of leks within the study area decreased from 12 to five (1976 to 1986).

Decreases in the number of Sharp-tailed Grouse at some leks corresponded to increases of grouse at other locations. For example, leks 8, 9, 10, 11 and 12 were within 3 km of each other. The total gain in grouse on leks 10 and 12 was 36 from 1975 to 1976, and the loss of grouse from leks 8, 9 and 11 was 41.

Discussion

Habitat change in the study area

Some regions within the NWMA changed from aspen parkland to aspen forest over 21 years. The mean rate of aspen increase of approximately 1.8% per year was greater than reported in similar studies. Bailey and Wroe (1974) found that in a 59-year period of aspen change in the parklands of Alberta, the net increase in brush cover was 3.2%; while the annual rate of invasion averaged 0.05%. Johnston and Smoliak (1968) calculated a rate of invasion onto grassland of 0.75% per year in Alberta.

In our study, the habitat distribution necessary to sustain a population of grouse within one km of a lek was no more than 44% closed aspen forest and 15% open aspen forest, at least 23% prairie, and 15 to 17% shrub (Refer to Table 1). Prairie should be kept at the upper limit or greater if possible and at least one contiguous area of prairie >20 ha should be present for each lek (Berger 1989). If grouse habitat changes through succession so closed aspen forest exceeds 56% and prairie decreases below 15%, Sharp-tailed Grouse will likely abandon the site. Caldwell (1976) suggested that a much higher proportion of grasses (>58%) is needed within 0.8 km of a lek. This was not found to be the case in our study.

Ammann (1957) found that Sharp-tailed Grouse in Michigan use an interspersion of cover types, including 6% forbs, 50% grass and woody cover, and 44% heavy wood cover with small grassy openings. The Minnesota Department of Natural Resources (1985) recommends that Sharp-tailed Grouse habitat be managed to include the following interspersion of cover types: 35% grass-legume, 15% small grain

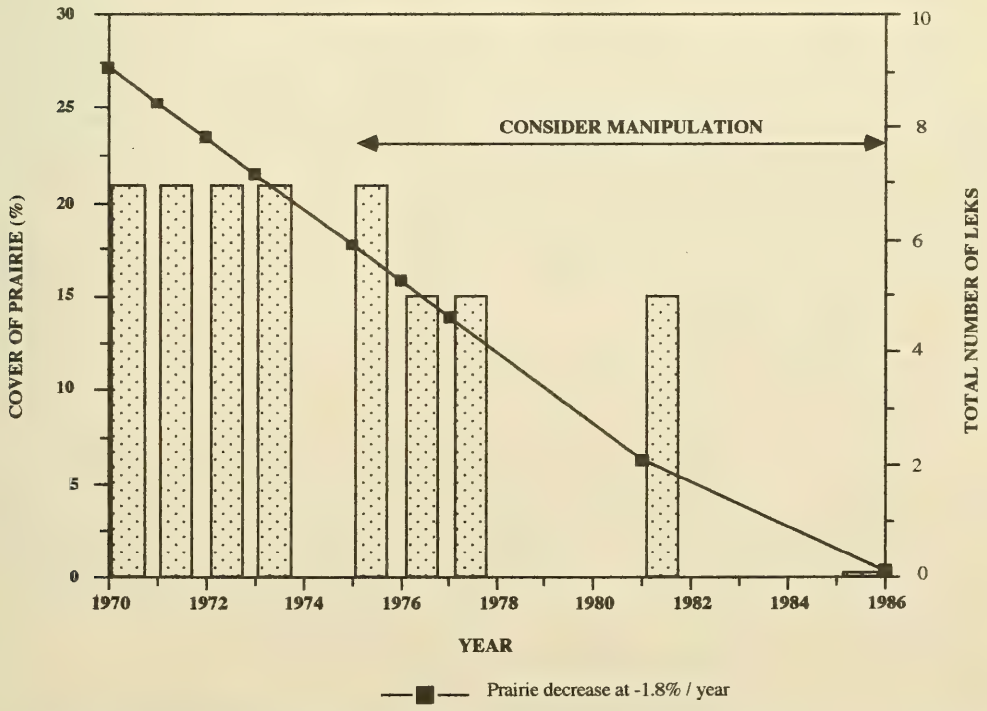


FIGURE 4. Model of the association between seven abondoned leks and corresponding prairie cover values in the Narcisse Wildlife Management Area, Manitoba.

cropland, 7% sedge-marsh, 16% willow, 9% lowland brush and trees and 18% off-site aspen-birch. This is a higher percentage of grass cover than calculated for this study.

Change in Sharp-tailed Grouse numbers

Sharp-tailed Grouse appeared to abandon leks because habitat quality was decreasing as aspen forest invaded prairie. Many authors have supported the conclusion that habitat change caused declines in local populations (Hamerstrom et al. 1961; Ammann 1963; Aldrich 1966; Evans 1968; Miller and Graul 1980; Berg et al. 1987). In Alberta, Moyles (1981) noted that the extent of trembling aspen cover within 0.8 km around a lek was inversely correlated with the number of Sharp-tailed Grouse observed on the lek and the total number of grouse recorded within 0.8 km of the lek. Pepper (1972) reported positive correlations between the number of summer-observed grouse and the amount of ungrazed native grass-shrub and tame haylands within 1.6 km of leks.

Modelling of lek and habitat change

If grouse are abandoning leks because habitat is becoming unsuitable (prairie becoming closed aspen forest), the total number of grouse should decline. More importantly, lek abandonment may indicate a decrease in habitat quality. Female and juvenile grouse use prairie and shrub for a significant portion of the nesting and rearing period. Aspen forest is used for cover, but if insufficient prairie and shrub exist, many young birds may not survive. Increases in intraspecific competition, poor quality food and cover, will decrease the average fitness of individuals and increase mortality rates. If females and broods do not have appropriate habitat, they should abandon sites and move to preferred habitat types. Furthermore, if females do not find appropriate nesting habitat near leks, they should disperse to other locations and possibly mate elsewhere. Gibson and Bradbury (1987) suggest that if no females visit leks, males will be forced to abandon these sites.

We suggest that annual change in habitat quality may cause an undetectable population change. Once habitat changes to some threshold limit, population change will be noticed. This change may occur gradually over several years before a response is observed. Examination of long-term habitat change and corresponding population change suggests that populations are affected by habitat quality. It may not be possible to examine trends within years due to seasonal variation within populations, but general trends can be examined among years.

A model (Figure 4) was developed which shows that after five years in this area, management is required to arrest the trend of aspen increase and prairie decrease. Data for the model were obtained from the seven abandoned leks (Figure 2). Assumptions underlying the model are: 1) that the aspen encroachment rate is 1.8% per year (and loss of prairie is 1.8% per year), and 2) that prairie cover within 1.0 km of the lek is 27%. We found that Sharp-tailed Grouse started to abandon leks when prairie decreased below 15% of the total area, therefore prairie within 1.0 km of the lek must be maintained above 15%.

Brown (1967) proposed a breeding unit habitat index for quantitatively rating habitat characteristics of Sharp-tailed Grouse leks. This index was similar to our model and was based on the concept that habitat factors within the breeding range of the unit served to: (1) maintain a segment of the male cohort having traditional ties to the lek, and (2) to attract hens and young cocks making shifts in seasonal distribution. The multiple factor method (Brown 1967) relies on estimates of aerial distribution and stand density of shrubs, topographic features surrounding the lek, disturbance factors and a qualitative evaluation of grassland associations. Our model differs since predictions of population changes are made by examining habitat composition and rate of change within 1.0 km of the lek. Our model also suggests a time when habitat revitalization should occur to sustain the breeding population.

This study was not designed to determine the optimal distribution of prairie and aspen for Sharp-tailed Grouse populations, but results indicated a distribution which adversely affected the study population. Aspen regeneration and loss of prairie occurs at different rates in different regions. To manage Sharp-tailed Grouse habitat, a manager must determine past and present distributions of prairie and the rate of habitat change. Only then can an estimate of the frequency and timing of habitat maintenance be made.

Acknowledgments

Graduate scholarships were awarded to the senior author during 1987 - 1988 by the University of Manitoba, Manitoba Department of Natural Resources, Natural Resources Institute, Manitoba Chapter of the Wildlife Society and the Manitoba Habitat Heritage Corporation. Further support was offered by the Machine Geography Department, University of Manitoba, and the Manitoba Remote Sensing Center. We extend special thanks for assistance to Alex McIlraith, Charles Burchill, Gwenn Berger and the anonymous referees who provided constructive comments and suggestions. We are also grateful to Murray Gillespie, Robert Jones, Donald Sexton and Larry Stene, who edited an earlier version of this manuscript.

Literature Cited

Aldrich, J. W. 1966. Geographic orientation of North American Tetraonidae. Journal of Wildlife Management 27: 529–545.

Ammann, G. A. 1957. The prairie grouse of Michigan. Michigan Department of Conservation Technical Bulletin. 200 pages.

Ammann, G. A. 1963. Status and management of Sharp-tail Grouse in Michigan. Journal of Wildlife Management 27: 802–809.

Bailey, A. W., and **R. A. Wroe.** 1974. Aspen invasion in a portion of the Alberta parklands. Journal of Range Management 27: 263–266.

Baydack, R. K. 1988. Characteristics of Sharp-tailed Grouse (*Tympanuchus phasianellus*) leks in the parklands of Manitoba. Canadian Field-Naturalist 102: 39–44.

Berg, W., D. Dickey, P. Watt, P. Telander, and **G. Davis.** 1987. Sharp-tailed Grouse: A draft management plan. Minnesota Department of Natural Resources, St. Paul. 17 pages.

Berger, R. P. 1989. Sharp-tailed Grouse habitat revitalization in the interlake region of Manitoba. M.N.R.M. Practicum, University of Manitoba. 138 pages.

Brown, R. L. 1967. Effects of land-use practices on sharp-tailed grouse. Montana Department of Fish and Game Report Number W-91-R-9. 11 pages.

Caldwell, P. J. 1976. Energetic and population considerations of Sharp-tailed Grouse in the aspen parkland of Canada. Ph.D. thesis, Kansas State University, Manhattan. 109 pages.

Cannon, R. W., and **F. L. Knopf.** 1981. Lek numbers as a trend index to prairie grouse populations. Journal of Wildlife Management 45: 776–778.

DeByle, D. V., and **R. P. Winokur.** 1985. Aspen: Ecology and management in the Western United States. U.S. Department of Agriculture, Forest Service General Technical Report RM-119.

Dixon, C. C. 1979. A management plan for the Narcisse wildlife management area. Manitoba Department of Mines, Natural Resources, and Environment. 52 pages.

Estes, J. E., and **G. A. Thorley.** 1983. Manual of remote sensing. Volume II: Interpretation and applications. Second edition. American Society of Photogrammetry, Falls Church. Pages 1233–2440.

Evans, K. E. 1968. Characteristics and habitat requirements for Greater Prairie Chickens and Sharp-tailed Grouse- a review of the literature. U.S. Department of Agriculture, Forest Service Conservation Research Report 12. 32 pages.

Gibson, R. M., and **J. W. Bradbury.** 1987. Lek organization in Sage Grouse: Variations on a territorial theme. Auk 104: 77–84.

Gratson, M. W. 1988. Spatial patterns, movements and cover selection by Sharp-tailed Grouse. Pages 158–192 *in* Adaptive strategies and population ecology of northern grouse Volume I: Population studies. *Edited by* A.T. Bergerund and M.W. Gratson. University of Minnesota Press, Minneapolis.

Hamerstrom, F., F. Hamerstrom, and **O. E. Mattson.** 1961. Status and problems of North American grouse. Wilson Bulletin 73: 284–294.

Johnston, A. M., and **S. Smoliak.** 1968. Reclaiming brushland in southwestern Alberta. Journal of Range Management 21: 404–406.

Miller, G. C., and **W. D. Graul.** 1980. Status of Sharp-tailed Grouse in North America. Pages 18–28 *in* Proceedings of the Prairie Grouse Symposium. *Edited by* P. A. Vohs, Jr., and F. L. Knopf. Oklahoma State University, Stillwater.

Minnesota Department of Natural Resources. 1985. Forest-wildlife guidelines to habitat management. Minnesota Department of Natural Resources, St. Paul. 114 pages.

Moyles, D. J. L. 1981. Seasonal and daily use of plant communities by Sharp-tailed Grouse. Canadian Field-Naturalist 95: 287–291.

Pepper, G. W. 1972. The ecology of Sharp-tailed Grouse during spring, and summer in the aspen parklands of Saskatchewan. Saskatchewan Department of Natural Resources, Wildlife Report No. 1. 56 pages.

Pratt, C. E., W. A. Ehrlich, F. P. Leclaire, and **J. A. Barr.** 1961. Detailed reconnaissance soil survey of Fisher and Teulon map sheet areas. Canada Department of Agriculture Soils Report No. 12, Winnipeg. 80 pages.

Rusch, D. H., M. M. Gillespie, and **D. I. McKay.** 1978. Decline of a Ruffed Grouse population in Manitoba. Canadian Field-Naturalist 92: 123–127.

Sexton, D. A. 1979. Breeding season movements and habitat use of female Sharp-tailed Grouse. M.S. thesis, University of Manitoba, Winnipeg. 152 pages.

Sexton, D. A., and **R. Dixon.** 1978. A habitat mapping study of the Chatfield area using airborne remote sensing. MS Report No. 78–76. Manitoba Department of Mines, Natural Resources and Environment. 9 pages.

Sisson, L. 1976. The Sharp-tailed Grouse in Nebraska. Nebraska Game and Parks Commission, Lincoln. 88 pages.

Received 21 January 1991
Accepted 30 October 1992

Discovery of a Living 900 Year-old Northern White Cedar, *Thuja occidentalis*, in Northwestern Québec

Sylvain Archambault[1] and Yves Bergeron

Groupe de recherche en écologie forestière and Département des sciences biologiques, Université du Québec à Montréal, CP 8888 Succursale A, Montréal, Québec H3C 3P8
[1]Present address: Centre d'études nordiques, Université Laval, Sainte-Foy, Québec G1K 7P4

Archambault, Sylvain, and Yves Bergeron. 1992. Discovery of a living 900 year-old Northern White Cedar, *Thuja occidentalis*, in northwestern Québec. Canadian Field-Naturalist 106(2): 192–195.

Thirty 500-900 year-old specimens of Northern White Cedar, *Thuja occidentalis*, were discovered growing on xeric rock outcrops in the Québec boreal forest, seven more than 700 years old. The oldest has an 869-year tree-ring sequence and an estimated germination age exceeding 900 years; this makes them among the oldest individuals for the species thus far noted in the literature. Such long tree-ring series offer great potential to extend the dendrochronological record in eastern Canada.

Key Words: Northern White Cedar, *Thuja occidentalis*, Québec, longevity, boreal forest.

Very few tree species can survive longer than three or four hundred years (Fowells 1965). In eastern Canada, long-lived trees are even less frequent, and there are only two species with reports of individuals older than 500 years: *Picea mariana* (Black Spruce), with a 504 year-old tree from the Québec subarctic (Payette et al. 1985) and *Thuja occidentalis* (Northern White Cedar), with an 1032 year-old tree recently discovered on the Niagara Escarpment, Ontario (Larson and Kelly 1991). Both these trees were aged by precise tree-ring counts. Knowing from previous work (Bergeron and Dubuc 1989) that old Northern White Cedars did occur at Lake Duparquet (Abitibi, Québec), a study was conducted (Archambault 1989) to assess the dendrochronological potential of the species as well as to evaluate the extent of these old individuals in the region. In this paper we report on the discovery of several old specimens of Northern White Cedar ranging from 500 to over 900 years of age. This confirms the great longevity attained by the species and offers enormous potential for future dendroclimatological studies. We also describe the growth habit of these trees as well as the sites in which they are found and offer various hypotheses to explain their exceptional age.

Study area

Lake Duparquet, a large body of water located in northwestern Québec (48°28'N, 79°17'W), has a surface area of nearly 50 km^2 and is dotted with approximately 170 islands ranging in size from a few square meters to more than 0.7 km^2. The climate is cold temperate with a mean annual temperature of 0.6°C, yearly total precipitation of 822.7 mm and a mean frost free period of 64 days (Anonymous 1982). The lake is at the southern limit of the boreal forest (Rowe 1972) and within the *Abies balsamea* (Balsam Fir)-*Betula papyrifera* (Paper Birch) domain as defined by Grandtner (1966). Xeric sites (very thin soils or rock outcrops) around the lake shores and islands are characterized by *Pinus banksiana* (Jack Pine) or *Pinus resinosa* (Red Pine) communities which, in the absence of fire, appear to evolve towards more shade tolerant species such as *Thuja occidentalis* or *Picea mariana* (Bergeron and Dubuc 1989).

Methods

An extensive search for old trees was carried out in the course of a dendroclimatological study (Archambault 1989). The shores and islands of Lake Duparquet were systematically surveyed to locate specimens of great age. Trees were sampled nondestructively using a Swedish increment borer which yielded 5.0 mm diameter cores. In the case of dead snags or fallen logs, cross sections could be obtained with the use of a chain saw. After the specimens were mounted, they were sanded with progressively finer textures of sandpapers. Crossdating of the specimens (Fritts 1976) by synchronizing the patterns of wide and narrow rings assured that an exact formation date could be assigned to every growth ring.

Age was determined by precise tree-ring counts but these yielded only minimum life spans since the central portions of the trees were, in a few cases, partially eroded. Estimates of true ages can be made by extrapolating the tree's overall radial growth rate to the missing core section (Wells et al. 1983). However, this method can easily overestimate the true age because the central rings are often wider than in the sampled outer portion. To offset this problem, ages were estimated by fitting an exponentially decreasing growth curve to the missing central portion, a procedure thought to represent more accu-

FIGURE 1. Photograph of the 902 year-old Northern White Cedar found on the rock outcrops of Lake Duparquet, Québec.

TABLE 1. List of Northern White Cedars with minimum ages of 700 years in Lake Duparquet.

Core length/ tree radius (%)	Minimum age (yr)[1]	Estimated age (yr)[2]
0.90	869	908
0.95	779	810
0.88	766	800
1.00	756	756
1.00	745	745
1.00	737	737
0.98	710	717

[1]Minimum age based on precise tree-ring counts
[2]Estimated age obtained by fitting a negative exponential growth curve to the missing pith section

rately the early growth rate, especially in the case of gymnosperms (Fritts 1976).

Results

Up to 30 trees with ring series in excess of 500 years were discovered, all growing on the fringe of rocky xeric sites both on the islands and shores. Seven of these trees were more than 700 years old (Table 1) and the oldest had a minimum age of 869 years and an estimated germination date of 908 years. The ratio of core length to tree radius was always close to 100%, an indication that the age estimates were likely not very far from the true ages. However, as no corrections were made to account for the sampling height (generally between 0.30 and 1.50 m), the true ages are probably somewhat higher.

The trees were of relatively small stature with a mean height of 4.6 m and a mean diameter at core height of 32.5 cm. The oldest tree was even smaller and had a total height of only 2.4 m and a diameter of 19.0 cm (Figure 1). Their appearance was often gnarled, with frequent apical mortality, sparse foliage, wind eroded trunks and strong cambial dieback. This last characteristic, often observed in very old trees (LaMarche 1969; Loehle 1988), results in a unilateral growth habit which gives them a slab-like appearance. Even though the trees have strongly eroded growth forms, their wood was always extremely sound with almost no signs of butt rot; sampled cores can thus often reach very close to the pith. Very slow radial growth rates have been measured, with a mean of only 0.36 mm/yr, an indication as to the harshness of their growth conditions. Despite extreme ages, most of the individuals were still producing seed-bearing cones albeit in very small numbers, in one case as few as 17 cones being noted.

Discussion

The very old Northern White Cedars documented here do not increase the known life span of the species (Table 2) but they add considerable insight into the geographical extent of these old trees. They seem to occur over much of the species distribution range (Table 2) and their presence on xeric rock outcrops, in the Lake Duparquet region as well as in southern Ontario (Larson and Kelly 1991), is interesting considering the severity of growth conditions found in such habitats. Many authors have noted that, for a given species, the oldest individuals often grow in the most extreme environments, either very dry (LaMarche 1969) or very cold (Edwards and Dunwiddie 1985; Payette et al. 1985), a fact that is still not well understood (Loehle 1988). The existence of these old trees at Lake Duparquet is even more surprising considering that they occur in the midst of the boreal forest where the fire cycle is approximately 100 years (Bergeron 1991). In the case of Northern White Cedar at Lake Duparquet, it seems that many factors contribute to its great longevity. The excellent decay resistance of the wood, its low water content and the very slow growth rate resulting in small stature all concur to maintain the structural integrity of the trees. On the other hand, the occurence of the old trees on rocky outcrops, where the ground cover is sparse and the trees widely spaced, often far from the main forest stands, has most probably contributed to slow the

TABLE 2. Record life spans for Northern White Cedars

Site	Minimum age (yr)[1]	Estimated age (yr)[2]	Reference
Niagara escarpment, Ontario	1032	–	Larson and Kelly (1991)
Niagara escarpment, Ontario	935	–	Larson and Kelly (1991)
Lake Duparquet, Québec	869	908	Present study
Lake Duparquet, Québec	779	810	Present study
Gaspé Peninsula, Québec	578	–	Cook (personal communication 1986)
Manitou Island, Michigan	530	–	Wells et al. (1983)
Upper Peninsula, Michigan	170	657	Wells et al. (1983)

[1]Minimum age based on precise tree-ring counts
[2]These estimated ages are purely speculative as they are based on incomplete cores and various calculation techniques.

spread of fires and enhanced the longevity of the trees (Archambault 1989).

More importantly, these findings show the great potential of Northern White Cedar to provide very long tree-ring chronologies in eastern Canada. Dendrochronological work in this region, and in most of eastern North America, has in fact always been hampered by a lack of long-lived individuals (Cook 1982). Since one of the goals of dendrochronology is to use tree-ring data as proxy records to reconstruct past events, whether they are climatic, ecological or geomorphic, long-lived species are always a clear asset. A second problem is that the individual trees used in dendrochronological work must show a common signal in their ring-width pattern (cross dating) to be of any use in dating past events. This common signal is quite often blurred, in our regions, by stand dynamic effects on ring-widths as well as by a weak response to climatic variables (Phipps 1982).

An 802-year tree-ring chronology was developed for the Lake Duparquet region using 38 individuals, 84% of which were over 450 years in age (Archambault and Bergeron 1992). Many facts indicate that this chronology retains a definite regional common signal: it shows excellent crossdating, it correlates well ($r = 0.63$, $p < 0.005$) with another Northern White Cedar chronology located 14 km away and it has 33.6% common variance in a chronology subsample. Good radial growth seems to be related to abundant precipitation in June as well as to low temperature during June or July. Likewise, the chronology has a close relation to a drought index during the growth season, a fact problably related to the occurrence of the trees on very dry rock outcrops. This species thus shows good dendroclimatic potential and with a sufficient sampling effort, it could help extend both the spatial and temporal coverage of the eastern tree-ring network.

Acknowledgments

This work forms part of the masters thesis of the first author and was generously supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Ministère de l'Education du Québec (FCAR). We wish to thank M. Rochefort and J. Tardif who helped with the field work. We also appreciated the helpful comments of two anonymous referees which greatly improved the manuscript.

Literature cited

Anonymous. 1982. Canadian climate normals. Canadian climate program. Environment Canada, Atmospheric Environment Service. Downsview. Ontario.

Archambault, S. 1989. Les cèdres blancs (*Thuja occidentalis* L.) à grande longévité du Lac Duparquet, Abitibi: une étude dendroclimatique et écologique. M.Sc. Thesis. Université du Québec à Montréal, Montréal. 119 pages.

Archambault, S., and **Y. Bergeron.** 1992. An 802-year tree-ring chronology from the Quebec boreal forest. Canadian Journal of Forest Research 22: 674–682.

Bergeron, Y. 1991. The influence of island and mainland lakeshore landscapes on boreal forest fire regimes. Ecology 72: 1980–1992.

Bergeron, Y., and **M. Dubuc.** 1989. Succession in the southern part of the Canadian boreal forest. Vegetatio 79: 51–63.

Cook, E. R. 1982. Eastern North America. Pages 126–133 *in* Climate from tree rings. *Edited by* M. K. Hughes, P. M. Kelly, J. R. Pilcher, and V. C. LaMarche, Jr. Cambridge University Press. Cambridge. 223 pages.

Edwards, M. E., and **P. W. Dunwiddie.** 1985. Dendrochronological observations on *Populus balsamifera* in northern Alaska, U.S.A. Arctic and Alpine Research 17: 271–278.

Fowells, H. A. 1965. Silvics of forest trees of the United States. USDA Forest Service Handbook Number 271.

Fritts, H. C. 1976. Tree rings and climate. Academic Press. New York. 567 pages.

Grandtner, M. M. 1966. La végétation forestière du Québec méridional. Presses de l'Université Laval. Québec. 216 pages.

LaMarche, V. C., Jr. 1969. Environment in relation to age in bristlecone pines. Ecology 50: 53–59.

Larson, D. W., and **P. E. Kelly.** 1991. The extent of old-growth *Thuja occidentalis* on cliffs of the Niagara Escarpment. Canadian Journal of Botany 69: 1628–1636.

Loehle, C. 1988. Tree life history strategies: the role of defenses. Canadian Journal of Forest Research 18: 209–222.

Payette, S., L. Filion, L. Gauthier, and **Y. Boutin.** 1985. Secular climate change in old-growth tree-line vegetation of northern Quebec. Nature 315: 135–138.

Phipps, R. L. 1982. Comments on interpretation of climatic information from tree rings, eastern North America. Tree Ring Bulletin 42: 11–22.

Rowe, J. S. 1972. Forest Regions of Canada. Environment Canada. Publication 1300. Ottawa. 172 pages.

Wells, J. R., P. W. Thompson, and **G. P. Fons.** 1983. Some Michigan Upper Peninsula big trees and their age estimates. Michigan Botanist 23: 3–10.

Received 18 March 1991
Accepted 20 June 1992

Electrophoretic Identification of the Marbled Salamander, *Ambystoma opacum,* on Kelleys Island, Lake Erie

LESLIE ANTHONY LOWCOCK[1,2] and JAMES P. BOGART[3]

[1]Department of Ichthyology and Herpetology, Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario M5S 2C6 and Ramsay Wright Zoological Laboratories, University of Toronto
[2]Current Address: Redpath Museum, McGill University, 859 Sherbrooke Street W., Montreal, Quebec H3A 2K6
[3]Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1 and Research Associate, Department of Ichthyology and Herpetology, Royal Ontario Museum

Lowcock, Leslie Anthony and James P. Bogart. 1992. Electrophoretic identification of the Marbled Salamander, *Ambystoma opacum,* on Kelleys Island, Lake Erie. Canadian Field-Naturalist 106(2): 196–199.

Kelleys Island is the second largest island in the western Lake Erie archipelago, an enigmatic biogeographic area in which all previously known species of the salamander genus *Ambystoma* are involved in intraspecific unisexual hybrid complexes. This paper documents the occurrence of *A. opacum* on Kelleys Island. Identification was made through electrophoretic comparison of tissue homogenates from unidentified larvae with tissue extracts from individuals whose identity was known. This demonstrates the utility of molecular markers for rapid identification in biological surveys without the need (time and expense) of raising animals to metamorphosis. The occurrence of this species on Kelleys Island is of both biogeographic and ecological interest.

Key Words: Marbled Salamander, *Ambystoma opacum*, Kelleys Island, Erie Islands, electrophoresis, larval identification, biogeography.

The Marbled Salamander, *Ambystoma opacum*, occurs widely throughout the eastern United States from the Gulf Coast through the Mississippi basin to the southern shores of Lakes Erie and Michigan, and along the Atlantic Coast to southern New England, with several disjunct populations occurring along the northern border of this range (Bishop 1943; Anderson 1967; Behler and King 1982; Conant and Collins 1991). Within this area, distribution is spotty, populations are localized, and the species is absent from mountainous regions (e.g., Anderson 1967; Minton 1972). In Ohio, records from near the Lake Erie shore are scarce (Thompson 1955; Anderson 1967; Pfingsten and Downs 1989) and Kraus and Shuett (1982) did not encounter this species in a herpetofaunal survey of the northwestern Ohio coastal zone. The paucity of localities in this region may be due to the extensive marshland of the area; *A. opacum* favors drier situations than most congeners (Bishop 1943). Prior to 1985, it had not been recorded from the Erie Islands. Pfingsten and Downs (1989) and Lowcock (1989) included it for Kelleys Island but provided no documentation. Previously, the only ambystomids recorded on this biogeographically enigmatic archipelago (see papers in Downhower 1989) in the western Lake Erie basin were those in interbreeding complexes which produce unisexual offspring [*A. lateral, A. texanum* and *A. tigrinum*] (Bogart et al. 1985; 1987).

During March, 1985, while collecting adults and eggs of *Ambystoma* on Kelleys Island, we encountered ambystomatid larvae in an advanced state of development (possessed all four limbs) that did not resemble those of any known syntopic species (*A. texanum, A. t. tigrinum*) or hybrid diploid or polyploid biotype (2n, 3n and 4n *A. laterale-texanum.* 3n and 4n *A. laterale-texanum-tigrinum*). The pools where the larvae were found contained no *Ambystoma* eggs. Adjacent breeding habitats were carpeted with eggs, but contained no larvae.

Our experience with diploid-polyploid hybrid complexes in this genus has shown us that morphological characters, particularly coloration, vary greatly in larvae. Thus, larvae of hybrid *Ambystoma* are not readily separated from those of sympatric non-hybrids, and the larvae in question could not be unambiguously assigned to any nominal species using keys available at the time of collection (Brandon 1961; Altig and Ireland 1984). Based on partial identity by key, collection circumstances and advanced development of the larvae, it was postulated that they were *A. opacum*, the only fall-breeding ambystomatid known to occur at that latitude. However, because the breeding habits of Kelleys Island hybrids had not yet been described, the possibility of earlier breeding, or more rapidly developing larvae than sympatric congeners, could not be ruled out for hybrid biotypes.

Allozyme electrophoresis has proven useful in sorting out genomic constitution of hybrid *Ambystoma* (Bogart 1982; Bogart and Licht 1986; Bogart et al. 1987; Lowcock and Bogart 1989) as well as for characterizing nominal species of the genus (Pierce and Mitton 1980; Shaffer 1984; Bogart

1989). We frequently use electrophoresis as an a priori method of species identification for unsorted samples of field-collected ambystomatid larvae by comparing electrophoretic patterns visualized for individual larvae with those of available tissues from several representatives of all sympatric/syntopic congeners. Employment of this methodology in the case at hand confirmed our hypothesis that the larvae were those of *A. opacum*. Although we raised some animals through metamorphosis for photographic purposes, rapid and unequivocal identification of larvae by use of molecular markers obviates the need to do so for identity confirmation.

Methods

On 26 March 1985 at 1700 hr, 30 larval *Ambystoma* were obtained from small (area = 2 m^2) woodland pools (air = 12°C, water = 8°C) on Kelleys Island, Erie County, Ohio (41°36'N, 82°41'W). Larvae were hand-collected by dipnet and stored in plastic buckets at 5°C until transport to the University of Guelph. Some larvae were removed whole to 1.5 ml cryotubes and frozen at -80°C until electrophoresis. Others were maintained at 20°C, fed brine shrimp and tubifex worms, and allowed to metamorphose. A number were sacrificed at this stage. Others were raised to a larger size before processing. Post-metamorphic individuals were fed crickets and earthworms and maintained in styrene boxes lined with wet paper towelling until adult coloration was established (up to two months). Processing for tissue and procedures for horizontal starch gel electrophoresis followed methods described in Bogart et al. (1985; 1987). Tissue homogenates and voucher specimens are currently maintained in the collection of JPB at the University of Guelph.

Results and Discussion

The results of electrophoresis were unequivocal with regard to the distinctness of the unidentified larvae. In comparison with syntopic Kelleys Island *Ambystoma* (*A. texanum; A. t. tigrinum*; 2n, 3n and 4n *A. laterale-texanum*; 3n and 4n *A. laterale-texanum-tigrinum*) and other sympatric mainland species (*A. maculatum; A. laterale; A. jeffersonianum*; 2n, 3n and 4n *A. laterale-jeffersonianum*), unique allelic products occurred at 20 of 27 loci examined [the latter are essentially those listed by Bogart et al. (1987), excluding general proteins and some unscored members of multi-locus isozyme systems]. These allelic products (allozymes) were identical to those from tissue extracts of *A. opacum* obtained in Connecticut. Within a subset of these loci — those commonly used to diagnose species and sort out genome composition in hybrid complexes on the Erie Islands (see Bogart et al. 1987), the putative *A. opacum* were easily identified, showing diagnostic products at 9 out of 13 loci (69%) compared to 46% (*A. laterale*), 46% (*A. t. tigrinum*) and 31% (*A. texanum*) for syntopic congeners (Table 1). Three out of four non-diagnostic products were shared with more than one taxon, indicating some conservation at those loci.

TABLE 1. Comparison of allelic product electromorph relative mobilities found in *Ambystoma opacum* with mobilities found at diagnostic loci[a] in *A. laterale, A. jeffersonianum, A. texanum*, and *A. tigrinum*. The mobilities are compared with the standard (100) mobility found in *A. laterale*.

	Electromorph mobility						
Locus	*Ambystoma laterale*	*Ambystoma jeffersonianum*[d]	*Ambystoma texanum*	*Ambystoma tigrinum*	*Ambystoma opacum*	Tissue[b]	Buffer system[c]
Acp-2	-100	-59	-100	-200	-25	L	2
Acon-1	100	79	128	66 & 128	80	L	1
Ck-A	100	127	100	110	110	HMS	1
Ck-C	-100	-380	-205	-205	-205	HMS	1
S-Aat-A	100	78	91 & 100	94	114	HMS	3
M-Aat-A	-100	-180	-100	-100	62	L	2
S-Icdh-A	100	142	142	142	142	HMS	2
Ldh-B	100	88	115 & 100	84	70	HMS	1
Ldh-A	130 & 100	100	100	0	100	HMS	1
S-Mdh-A	100	176	100 & 61	100	200	HMS	2
M-Mdh-A	100	100 & 18	18	34	135	HMS	2
Pgm-A	100	97	104	100	92	L	1
S-Sod-A	100	37	67	12 & 37	78	L	2

[a]Diagnostic loci are those primarily used to distinguish species and genome composition in hybrids. Relative mobilities are those established by Bogart et al. (1985, 1987), Bogart (1989) and Lowcock (1989) [see these references for loci E.C. numbers]. Locus nomenclature follows Lowcock (1989).

[b]L, Liver; HMS, heart, skeletal muscle, and spleen.

[c](1) Amine-citrate, pH 6.5; (2) Tris-citrate, pH 6.7; (3) Poulik, pH 8.7

[d]Mainland only — not found on Erie Islands.

Differences between *A. opacum* and congeners were not confined to allelic products and included isozyme configuration and epigentic (or post-translational modification) patterns (e.g., both cases were observed for Mdh). Additionally, electrophoretic differences were apparent between *A. opacum* and non-Erie Island hybrid complexes as well as non-hybrid mainland species. The extreme divergence of electrophoretic patterns from those displayed by congeneric species and their interspecific hybrids, and the complete synonymy with the Connecticut material proved our original hypothesis that the larvae were *A. opacum*.

Although allozyme electrophoresis has perhaps seen its heyday as a major systematic tool, having been usurped by various nucleic acid restriction fragment and sequencing procedures, the utility of this and other molecular markers as aids to faunal investigations in problematic areas like the Erie Islands remains high. The alternative methodology, at least in the case of amphibians that cannot be confidently identified in larval form, is to raise the animals through metamorphosis, often incurring substantial costs in time, space, labor and materials. Metamorphosed individuals from our sample could not have confirmed our hypothesis until the characteristic color pattern of *A. opacum* developed several weeks after transformation. The lag time between molecular and morphological identification was close to two months.

The occurrence of *A. opacum* on Kelleys Island is of considerable biogeographic and ecological significance, because the Erie Islands represent a distributional limit for several species of *Ambystoma* (e.g., see Lowcock 1989). For example, *A. t. tigrinum*, whose overall range is similar to that of *A. opacum*, is discontinuously distributed throughout the western Lake Erie basin, including the archipelago. Assuming at least a loose congeneric association between the post-glacial movements of *A. tigrinum* and *A. opacum* in this area (Lowcock 1989), it is not surprising that the latter occurs as a relict on Kelleys Island. That it was not detected or recorded during 130 years of intensive clearcutting, agriculture and mining on an 8 sq. km island is interesting, but not unusual, since *A. texanum* was only confirmed on nearby Pelee Island, Ontario, 30 years ago (Uzzell 1962). Given this, it is possible that *A. opacum* may yet be found on other Erie Islands.

Alternatively, we must consider the remote possibility that *A. opacum* occurs on Kelleys as a result of recent human introduction. Although documentation of mammal introductions to some Erie Islands exist (e.g., Campbell et al. 1989), nothing is known and no evidence exists with respect to reptiles (King 1989) or amphibians. The large itinerent summer human population of the island would certainly allow increased opportunity for such an introduction, however, the situation in which the larvae were discovered (deep in the forest and far removed from human habitation) strongly suggests that the population is natural.

Acknowledgments

We thank Kirt Zettler of The Kelleys Island Wine Co. for his gracious support of our field work and Linda Nyilas for saying "how come the larvae in this puddle have feet already?" Cliff Zeyl assisted in raising larvae and running gels. Mike Klemmens of the American Museum of Natural History provided the Connecticut samples. Nick Mandrak reviewed the manuscript. The study was supported by NSERC grant A9866 to JPB, and manuscript preparation was partially assisted by NSERC grant A3148 to R. W. Murphy.

Literature Cited

Altig, R., and **P. H. Ireland.** 1984. A key to salamander larvae and larviform adults of the United States and Canada. Herpetologica 40(2): 212–218.

Anderson, J. D. 1967. *Ambystoma opacum*. Pages 46.1–46.2 *in* Catalogue of American amphibians and reptiles. Society for the Study of Amphibians and Reptiles, Ohio.

Behler, J. L., and **F. W. King.** 1982. The Audobon Society Field Guide to North American Reptiles and Amphibians. Knopf, New York. 719 pages.

Bishop, S. C. 1943. Handbook of salamanders. Comstock. Ithaca, New York. 555 pages.

Bogart, J. P. 1982. Ploidy and genetic diversity in Ontario salamanders of the *Ambystoma jeffersonianum* complex revealed through an electrophoretic examination of larvae. Canadian Journal of Zoology 60: 848–855.

Bogart, J. P. 1989. A mechanism for interspecific gene-exchange via all-female salamander hybrids. Pages 170–179 *in* Evolution and Ecology of Unisexual Vertebrates. *Edited by* R. M. Dawley and J. P. Bogart. New York State Museum, Bulletin 466.

Bogart, J. P., and **L. E. Licht** 1986. Reproduction and the origin of polyploids in hybrid salamanders of the genus *Ambystoma*. Canadian Journal of Genetics and Cytology 28: 605–617.

Bogart, J. P., L. E. Licht, M. J. Oldham, and **S. J. Darbyshire.** 1985. Electrophoretic identification of *Ambystoma laterale* and *Ambystoma texanum* as well as their diploid and triploid interspecific hybrids (Amphibia: Caudata) on Pelee Is., Ontario. Canadian Journal of Zoology 63: 340–347.

Bogart, J. P., L. A. Lowcock, C. W. Zeyl. and **B. K. Mable.** 1989. Genome constitution and reproductive biology of hybrid salamanders, genus *Ambystoma*, on Kelleys Island in Lake Erie. Canadian Journal of Zoology 65: 2188–2201.

Brandon, R. A. 1961. A comparison of the larvae of five northeastern species of *Ambystoma* (Amphibia, Caudata). Copeia 1961: 377–383.

Campbell, C. A., L. B. Needham and **S. M. Nevin.** 1989. The Mammals of Pelee Island. Pages 150–162 *in* The Biogeography of the Island Region of Western Lake

Erie. *Edited by* J. E. Downhower. Ohio State University Press, Columbus.

Conant, R., and **J. T. Collins.** 1991. Reptiles and Amphibians: Eastern and Central North America. Houghton Mifflin, Boston. 450 pages.

Downhower, J. E. 1989. *Editor.* The Biogeography of the Island Region of Western Lake Erie. Ohio State University Press. Columbus.

King, R. B. 1989. Biogeography of reptiles on islands in Lake Erie. Pages 123–133 *in* The Biogeography of the Island Region of Western Lake Erie. *Edited by* J. E. Downhower. Ohio State University Press. Columbus.

Kraus, F., and **G. W. Shuett.** 1982. A herpetofaunal survey of the coastal zone of northwest Ohio. Kirtlandia 36: 21–54.

Lowcock, L. A. 1989. Biogeography of hybrid complexes of *Ambystoma*: Interpreting unisexual-bisexual genetic data in space and time. Pages 180–208 *in* Evolution and Ecology of Unisexual Vertebrates. *Edited by* R. M. Dawley and J. P. Bogart. New York State Museum, Bulletin 466.

Lowcock, L. A., and **J. P. Bogart.** 1989. Electrophoretic evidence for multiple origins in the *Ambystoma laterale-jeffersonianum* complex. Canadian Journal of Zoology 67: 350–356.

Minton, S. A. 1972. Amphibians and reptiles of Indiana. Indiana Academy of Science. Indianapolis. 346 pages.

Pfingsten, R. A., and **F. Downs.** 1989. Salamanders of Ohio. Bulletin of the Ohio Biological Survey 7(2). Columbus, Ohio.

Pierce, B. A., and **J. B. Mitton.** 1980. Patterns of allozyme variation in *Ambystoma tigrinum mavortium* and *A. t. nebulosum.* Copeia 1980(4): 594–605.

Shaffer, H. B. 1983. Biosystematics of *Ambystoma rosaceum* and *A. tigrinum* in northwestern Mexico. Copeia 1983(1): 67–78.

Thompson, F. G. 1955. Three notable records of the marbled salamander in northern Ohio. Herpetologica 11(3): 183–184.

Uzzell, T. M. 1962. The small-mouthed salamander, new to the fauna of Canada. Canadian Field-Naturalist 76(3): 182.

Received 13 March 1991
Accepted 6 May 1992

Red Foxes, *Vulpes vulpes*, as Biological Control Agents for Introduced Arctic Foxes, *Alopex lagopus*, on Alaskan Islands

Edgar P. Bailey

U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, Homer, Alaska 99603

Bailey, Edgar P. 1992. Red Foxes, *Vulpes vulpes*, as biological control agents for introduced Arctic Foxes, *Alopex lagopus*, on Alaskan Islands. Canadian Field-Naturalist 106(2): 200–205.

Fox populations introduced before 1930 for fur farming have devastated breeding avifauna on numerous islands in southern Alaska. To restore populations of the endangered Aleutian Canada Goose, seabirds, and other avifauna on Alaskan islands, foxes must first be removed. Arctic and Red foxes are not sympatric on islands in Alaska, except on Nunivak Island. More than 40 years of eradication efforts have eliminated foxes from only 21 islands. During the fox farming era Arctic Foxes inadvertently were eliminated by later Red Fox releases on several islands. I introduced sterile Red Foxes on two Aleutian Islands in 1983 and 1984 to determine their ability to eradicate Arctic Foxes. By the summer of 1992 some Red Foxes still remained on one island, but Arctic Foxes apparently were absent from both. Such island introductions on a broader scale should be a valuable tool to restore native ecosystems.

Key Words: Alaskan Islands, Arctic Foxes, *Alopex lagopus*, Biological Control, Introduced Species, Red Foxes, *Vulpes vulpes*.

Initially terrestrial mammals were absent from most western Alaska islands south of the Bering Sea winter ice pack. Arctic Foxes (*Alopex lagopus*) from the Commander Islands (Russia) were introduced to Atto Island (Figure 1) in the western Aleutian Islands in 1750 (Black 1984; Nelson 1887; Janson 1985). Arctic Fox were then released on Atka Island in the central Aleutians around 1790 (Black 1984). Both Arctic Fox and Red Fox (*Vulpes vulpes*) were introduced to more Alaskan islands by the Russian-American Company in the early 1800s, and in the 1920s and 1930s fox farming activities reached a peak (Jones and Byrd 1979). Foxes were released on over 450 islands with no indigenous terrestrial predators from the western Aleutians to the Alexander Archipelago (Bailey 1993, Figure 1). A sharp reduction in fur prices during the Great Depression, higher salmon prices, and World War II virtually brought an end to fox farming in Alaska (Merritt and Fuller 1977).

By 1811 Aleuts at Atto and Atka islands already were having to seek seabirds on outlying islands, and other accounts of birds vanishing from various islands with introduced fox were made by early explorers (Black 1984; Dall 1874; Nelson 1887). The Aleutian Canada Goose (*Branta canadensis leucopareia*), once widespread in the Aleutians and probably on islands south of the Alaska Peninsula, survived only on three remote islands, which were spared from fox introductions (Jones 1963; Bailey and Trapp 1984; Hatch and Hatch 1983). Many seabird colonies and entire insular populations of some species of fossorial and ground-nesting birds disappeared in the Aleutians and south of the Alaska Peninsula (Murie 1959). Nocturnal nesting seabirds, which generally prefer soil burrows for nest sites, suffered the most from fox introductions (Bailey 1993).

Recent insular surveys revealed profound differences in seabird diversity, abundance, and colony site selection between islands that have or previously had foxes and those that have been free of fox introductions (Bailey 1976, 1977, 1978; Bailey and Faust 1980a, 1980b, 1984; Byrd and Day 1986).

Dramatic population recoveries of some seabirds, ptarmigan (*Lagopus* spp.), and waterfowl recently have been witnessed in the Shumagin Islands and in the Aleutians following eradication of fox on several islands (personal observation; G. V. Byrd, J. L. Trapp and C. F. Zeillemaker. 1992. Removal of introduced Arctic Fox in the Aleutian Islands: a method for restoring natural biodiversity. Unpublished report, U.S. Fish and Wildlife Service, Adak, Alaska. 14 pages).

In 1949, efforts to eradicate previously introduced fox populations began in the Aleutian Islands National Wildlife Refuge (Jones and Byrd 1979). Despite the expenditure of tens of thousands of dollars during 40 years, introduced fox appear to have been eliminated from only 21 islands. Current inability to use toxicants even as an alternative for trap-wise foxes will render eradication efforts on some islands futile. This is the main reason experimental biological control was tested.

Evidence for predation and/or competitive exclusion of Arctic Foxes by Red Foxes on islands is very strong. In 1886, an introduced lone, male Red Fox destroyed within a few months all Arctic (formerly called "blue") Foxes on Chowiet Island in the Semidi Islands, south of the Alaska Peninsula. Red Foxes later reportedly swam to Chowiet from a nearby island and again killed Arctic Foxes on the island

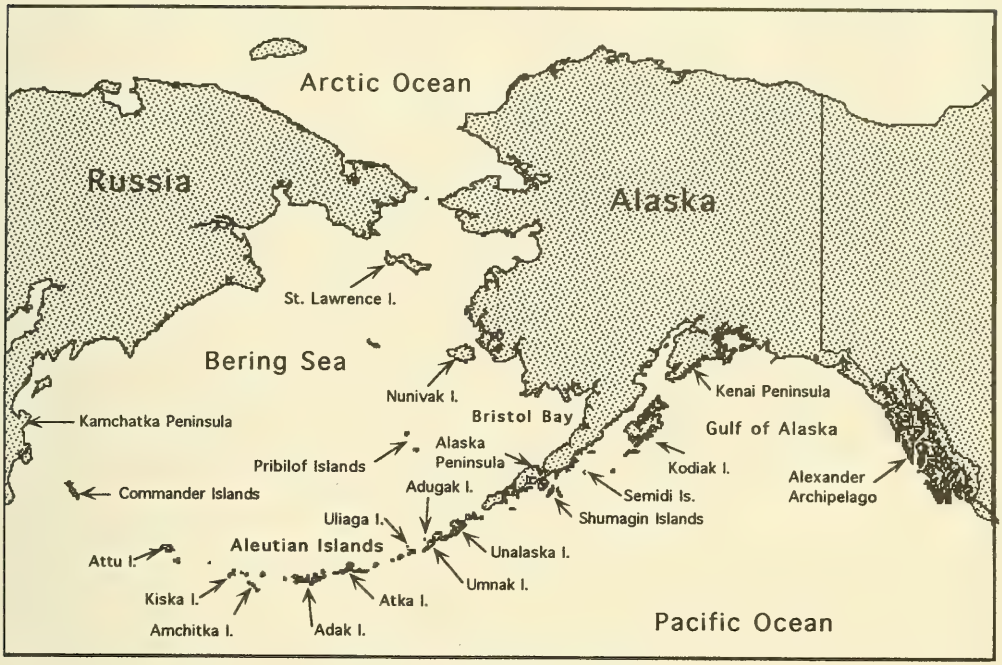


FIGURE 1. Aleutian Islands, Alaska.

(Bower and Aller 1917). Ugak Island, near Kodiak, was first stocked in 1891 with Red Foxes. About three years later blue foxes were added, and "as always appears to be the case when black (red) and blue foxes are placed together, the blue foxes were soon exterminated" (Bower and Aller 1917: 132). Concerning Ugak Island, Evermann (1914: 24) stated, "The two kinds of foxes did not thrive well together, for the natural enmity between them led to continued fighting which finally resulted in the extermination of the blue ones." Murie (1959) also heard much about the antipathy between Red and Arctic foxes in the Aleutians. Swanson (1982: 66) stated that "if you put blue foxes on an island with Red Foxes, the blue foxes disappeared."

Thus, fox farmers knew from field experience that both species of fox cannot coexist on the same island. My interviews with many former fox farmers as well as reviews of old literature revealed that Arctic Fox disappeared on at least 14 islands where Red Fox also were present. Furthermore, the evidence gathered from numerous islands where foxes are known to now occur reveals that only Nunivak Island (450 000 ha) in the Bering Sea sustains both species (Manville and Young 1965), and this island is connected to the mainland by ice in winter. On the Walrus Islands in Bristol Bay Red Foxes apparently exclude Arctic Foxes. Both species of fox can reach these small islands by ice in winter (P. Arneson personal communication).

Interspecific competition between canid species in North America is well documented. Coyotes (*Canis latrans*), once numerous on Isle Royale in Michigan, vanished within 10 years after the arrival of Wolves (*C. lupus*) (Mech 1970). Small carnivore populations increased in three western states after Coyote control (Robinson 1961), and after Coyote poisoning in Saskatchewan Red Foxes markedly increased in numbers (Stoudt 1971). Marsh (1938) found that there were no Arctic Foxes on the west side of Hudson Bay where Red Foxes had their dens and that Red Foxes often attacked and killed trapped Arctic Foxes. Recent studies further confirm that Red Fox compete with and prey on Arctic Fox in Scandinavia and probably restrict the distribution and recovery of scarce Arctic Fox populations in this region (Hersteinsson et al. 1989, Frafjord et al. 1989). Hersteinsson and Macdonald (1992) contend that the southern limit of the range of the Arctic Fox is determined through interspecific competition by the distribution and abundance of Red Foxes. The larger Red Fox dominates the smaller Arctic Fox in direct competition and has been invading more northerly areas and is ousting Arctic Foxes from parts of their range.

Rudzinski et al. (1982) confirmed the dominance of Red over Arctic foxes in an enclosure. They concluded that the larger and more aggressive Red Fox will outcompete the Arctic Fox by usurping dens and other limited resources. Chesemore (1975) regarded

Red Fox as one of the predators of Arctic Fox and a possible factor in Arctic Fox distribution in Alaska. Johnson and Sargeant (1977) thoroughly analyzed canid population histories in the Prairie Pothole region and concluded that unknown mechanisms were involved in the suppression of small canids by larger ones. Competitive exclusion would be especially acute on islands where the smaller species could not escape.

This paper presents observations of Arctic and Red foxes after the introduction of Red Foxes on two islands in the Aleutians.

Study Area and Methods

In June 1983 three male Red Foxes were captured in padded leg-hold traps near the Aleut village of Nikolski located on Umnak Island in the eastern Aleutians (Figure 1) and, after being held briefly in

TABLE 1. Summary of fox introductions and monitoring of Adugak and Uliaga islands.

1925	—	Adugak Island stocked with Arctic Fox; 68 pelts removed by 1939 (U.S. Fish and Wildlife Service files).
1930	—	Uliaga Island stocked with 21 Arctic Foxes; 185 pelts removed by 1936 (U.S. Fish and Wildlife Service files).
1936-1937	—	Murie (1959) analyzed 132 Arctic Fox scats on Uliaga. Seabird remains were found in 75% of scats.
August 1980	—	Five or 6 Arctic Foxes observed on Adugak.
June 1982	—	Four people hiked southeast portion of Uliaga and camped on southeast beach; Arctic Fox trails and tracks on beach, and 1 Arctic Fox observed.
May 1983	—	Visited Adugak for 1 h; saw Arctic Fox and heard others bark.
June 1983	—	Three male Red Foxes from Umnak released on Adugak; saw 6–8 Arctic Foxes during 6 h.
September 1983	—	Spent 3 h on Adugak. At least 4 Arctic Foxes and 2 Red Foxes sighted. Arctic Fox acted more wary and no barking heard, except when one was cornered in boulders.
April 1984	—	On Adugak 1/2 day with 4 people; saw 2 Red and 2 Arctic Foxes.
May 1984	—	Released 5 pairs of sterile Red Foxes on Uliaga. No Arctic Foxes seen but found an active den and tracks during brief visit.
August 1984	—	One male Arctic Fox mistakenly shot on Adugak; 2 people walked opposite directions for 2 1/2 h but saw no Red Foxes. Three Red Foxes seen on southeast beach of Uliaga during 3 1/2 h survey.
August 1985	—	Brief visit to Uliaga and Adugak; one Red Fox seen on Adugak (3–4 h, 2 people).
September 1987	—	Four people covered most of Uliaga afoot and circumnavigated it by inflatable boat; 1 Red Fox observed and 1 Red Fox trapped (8 leg-hold and 7 box traps for 3 days). Walked all of Adugak Island with 4 people twice and east 2/3 of island 7 times with up to 6 people. Nine leg-hold and 3 box traps set for 2 days. Only Red Fox fur and tracks found.
September 1988	—	Four people stopped on Uliaga for 2 h and found tracks, a few scats, and some Red Fox fur on the beach on the east side. Many trails on bench on south side appeared little used and were largely overgrown.
May 1990	—	Six people walked abreast across Adugak and observed 1 and possibly 2 Red Foxes; no sign of Arctic Fox. Nine people spent 4 h walking the east side of Uliaga; only fox tracks found.
June 1990	—	Nine people walked entire east and south side of Uliaga; 8 leg-hold traps set overnight. One Red Fox was sighted, and 1 Red Fox was trapped and released on a beach in the same area. This fox was caught on the same beach as the one trapped in 1987. One Red Fox den found; no Arctic Fox sign noted.
May 1991	—	Three people spent 1 day on Uliaga and found fresh Red Fox fur and tracks.
July 1992	—	Four people noted no fox sign on Adugak after 2 h. Recent Red Fox sign was found on Uliaga.

outdoor pens were translocated to Adugak (65 ha), a low, relatively flat island lying 13 km northwest of Nikolski.

During March and April 1984, five male and five female Red Foxes were captured and held in separate pens at Nikolski. By late April it was certain that none of the females was pregnant. At this time a veterinarian sterilized the males by vasectomy. Approximately three weeks later the 10 foxes were released on Uliaga, a rugged 940-ha island located 32 km northwest of Nikolski. Several brief opportunistic visits to both islands to check on the status of both species of fox were made from boats passing by in 1984 and 1985 (Table 1).

Four days were spent camping on Uliaga Island in September 1987 to ascertain whether any fox of either species remained following the release of sterile pairs of Red Fox there 39 months earlier (Table 1). Both box and padded leg-hold traps were set to see what foxes survived. After leaving Uliaga in 1987, more than two days were spent checking Adugak Island. Additional visits were made to Uliaga Island in 1988, 1990, 1991, and 1992 (Table 1). All of Adugak Island also was again walked in May 1990 and 1992.

Results

Adugak Island — At the time of release of Red Foxes on Adugak in June 1983 at least six Arctic Foxes were noted while walking the entire island (Table 1). Three months later four Arctic and two Red Foxes were observed. In April 1984, two Arctic and two Red Foxes were noted; four months later only one Arctic Fox was sighted. One Red Fox was sighted in August 1985.

In 1987, despite repeatedly walking over Adugak and trapping for two nights, no foxes were encountered. However, large tracks and guard hairs found on a trail strongly suggested that at least one Red Fox remained on the island. By 1987 the fox population had undergone a profound change since the introduction of Red Foxes over four years earlier. In 1983 Arctic Foxes were commonly seen and heard barking, but after release of the Red Foxes the Arctic Foxes appeared more wary, less active, and no longer barked when people landed. Also, they were never seen near Red Foxes.

In 1990, at least one and probably two Red Foxes were seen by different teams of observers on opposite ends of Adugak. A den with Red Fox fur also was found, but there was no evidence of Arctic Fox. A fisherman reportedly saw a Red Fox on this island in 1991 (S. Ermeloff, personal communication), but no fox sign was found in 1992 (J. Wraley, personal communication).

Uliaga Island — When I surveyed Uliaga in 1982, I saw an Arctic Fox as well as numerous trails, scats, and tracks on beaches (Table 1). Arctic Fox definitely were still present on Uliaga when Red Fox were released in 1984 because tracks and an active den were found during the brief visit. Arctic Foxes also still thrived on neighboring islands in 1990.

No foxes were seen in late 1985 on a brief visit to Uliaga. During September 1987, one Red Fox was sighted, and one Red Fox was trapped and released. Hand-held predator calls failed to attract any foxes. A freshly dug Red Fox den was found on a grassy bench crisscrossed with trails. Several old, smaller, overgrown dens, believed to be those of former Arctic Fox, also were located.

A brief visit in September 1988 revealed Red Fox fur as well as fox scat and tracks. In June 1990, an active Red Fox den was discovered. One Red Fox was sighted, and one Red Fox was captured and released in the same general area. I found fresh Red Fox sign in May 1991 and July 1992.

Discussion

Arctic Foxes apparently have disappeared from both Adugak and Uliaga islands since the release of Red Foxes. While it appears certain that three male Red Foxes eliminated an adult population of six or more Arctic Foxes on Adugak, the number of Arctic Foxes present on Uliaga when Red Foxes were released was unknown. Based on the island's size, type of shoreline, topography, food resources, extent of fox sign, and comparisons with similar nearby islands on which I trapped all foxes, I believe that Uliaga probably could support no more than 20–30 adults. The ratio of Red to Arctic Fox on these two islands was probably about 1 to 2. Apparently this number of Red Foxes was sufficient to monopolize insular resources completely, and it appears that either lone males or sterile pairs can be used as biological control agents.

The specific mechanism by which Red Foxes eliminate Arctic Foxes is not known, but since both species were still present for at least 14 months on Adugak, evidently Red Foxes did not simply quickly kill adult Arctic Foxes. Red Foxes also did not kill Arctic Foxes in enclosure experiments (Rudzinski et al. 1987). I suspect that Red Foxes usurp dens, kill Arctic Fox pups, and exclude Arctic Foxes from the best feeding beaches. Thus, probably both exploitation and interference competition are involved in addition to predation.

Management Implications

Red Foxes should be placed only on small or moderate sized islands where accessible seabird colonies no longer exist. Temporary additional predation by Red Foxes could eliminate relict populations of Rock Ptarmigan (*Lagopus mutus*) or some passerine species on certain small islands where they are introduced. Ptarmigan have vanished from several of the Aleutian Islands since Arctic Fox were

introduced (Murie 1959, personal observation). On some large islands, such as Gareloi with hundreds of thousands of accessible crevice-nesting seabirds, addition of numerous Red Foxes conceivably could have a detrimental effect if they joined Arctic Foxes concentrated at colony sites, resulting in an inability of the birds to swamp their predators. However, use of Red Foxes as control agents would never be attempted on a large island because too many foxes would be necessary.

Past attempts to introduce predators, parasites, and diseases for biological control of vertebrates reportedly have failed (Schmidt 1985). If introduced nonbreeding Red Foxes have exterminated Arctic Foxes on Uliaga and Adugak islands, as appears to be the case, more widespread use of this technique will help restore biodiversity and bird population sizes on additional Alaskan islands.

Acknowledgments

Dr. P. Gipson, formerly with the Alaska Cooperative Wildlife Research Unit, and K. Lourie provided some of the copies of references used in this paper. S. Ermeloff trapped, cared for, and helped translocate Red Foxes to two islands. Dr. A. Hurley performed the vasectomies. T. Early, W. Stephensen, J. Wraley, and other U.S. Fish and Wildlife Service personnel also assisted the project. T. Fellows typed the manuscript.

Literature Cited

Bailey, E. P. 1976. Breeding bird distribution and abundance in the Barren Islands, Alaska. Murrelet 57: 2–12.

Bailey, E. P. 1977. Distribution and abundance of marine birds and mammals along the south side of the Kenai Peninsula, Alaska. Murrelet 58: 58–72.

Bailey, E. P. 1978. Breeding seabird distribution and abundance in the Shumagin Islands, Alaska. Murrelet 59: 82–91.

Bailey, E. P. 1993. Fox introductions on Alaskan islands-history, impacts on avifauna, and eradication. U.S. Fish and Wildlife Service Resource Publication. *In press.*

Bailey, E. P., and **N. H. Faust.** 1980a. Summer distribution and abundance of marine birds and mammals in the Sandman Reefs, Alaska. Murrelet 61: 6–19.

Bailey, E. P., and **N. H. Faust.** 1980b. Summer distribution and abundance of marine birds and mammals between Mitrofania and Sutwik islands south of the Alaska Peninsula. Murrelet 62: 34–42.

Bailey, E. P., and **N. H. Faust.** 1984. Distribution and abundance of marine birds breeding between Amber and Kamishak bays, Alaska, with notes on interaction with bears. Western Birds 15: 161–174.

Bailey, E. P., and **J. L. Trapp.** 1984. A second wild breeding population of Aleutian Canada geese. American Birds 38: 284–286.

Black, L. T. 1984. Atka — an ethnohistory of the western Aleutians. Limestone Press, Kingston, Ontario. 219 pages.

Bower, W. T., and **H. D. Aller.** 1917. Alaska fisheries and fur industries in 1915. Department of Commerce, Bureau of Commercial Fisheries. Washington: Government Printing Office. Pages 109–140.

Byrd, G. V., and **R. H. Day.** 1986. The avifauna of Buldir Island, Aleutian Islands, Alaska. Arctic 39: 109–118.

Chesemore, D. L. 1975. Ecology of the arctic fox (*Alopex lagopus*) in North America - a review. Pages 143–163 *in* The Wild Canids. *Edited by* M. W. Fox. Van Nostrand Reinhold Co., New York, NY. 508 pages.

Dall, W. H. 1874. Notes on the avifauna of the Aleutian Islands, especially those west of Unalaska. Proceedings of the California Academy of Sciences 5: 270–281.

Evermann, B. W. 1914. Alaska fisheries and fur industries in 1913. Department of Commerce, Bureau of Fisheries Document number 797. Washington: Government Printing Office. Pages 13–17.

Frafjord, K., D. Becker, and **A. Angerbjorn.** 1989. Interactions between arctic and red foxes in Scandinavia — predation and aggression. Arctic 42: 354–356.

Hatch, S. A., and **M. A. Hatch.** 1983. An isolated population of small Canada geese on Kaliktagik Island, Alaska. Wildfowl 34: 130–136.

Hersteinsson, P., A. Angerbjorn, K. Frafjord, and **A. Kaikusalo.** 1989. The arctic fox in Fennoscandia and Iceland: management problems. Biological Conservation 49: 67–81.

Hersteinsson, P., and **D. W. Macdonald.** 1992. Interspecific competition and the geographical distribution of red *Vulpes vulpes* and arctic foxes *Alopex lagopus*. Oikos 64: 505–515.

Janson, L. 1985. Those Alaska blues. Alaska State Document Alaska Historical Commission, Anchorage, Alaska. 180 pages.

Johnson, D. H., and **A. B. Sargeant.** 1977. Impact of red fox predation on the sex ratio of prairie mallards. Wildlife Research Report 6, U.S. Fish and Wildlife Service, Washington, D.C. 56 pages.

Jones, R. D., Jr. 1963. Buldir Island, site of a remnant breeding population of Aleutian Canada geese. Wildfowl 14: 80–84.

Jones, R. D., Jr., and **G. V. Byrd.** 1979. Interrelations between seabirds and introduced animals. Pages 221- 226 *in* Conservation of marine birds of northern North America. Papers from the International Symposium at Seattle, Washington, May 1975. *Edited by* J. C. Bartonek and D. N. Nettleship. Wildlife Research Report 11, U.S. Fish and Wildlife Service, Washington, D.C.

Manville, R. H., and **S. P. Young.** 1965. Distribution of Alaskan Mammals. Circular number 211, Bureau of Sport Fisheries and Wildlife, U.S. Government Printing Office, Washington, D.C. 74 pages.

Marsh, D. B. 1938. Influx of the red fox and its color phases into the Barren Lands, Canadian Field-Naturalist 52: 60–61.

Mech, L. D. 1970. The Wolf. Natural History Press, Garden City, NY. 384 pages.

Merritt, M. L., and **R. G. Fuller.** 1977. The environment of Amchitka Island, Alaska. Technical Information Center, Energy Research and Development Administration, Oak Ridge, Tennessee. 682 pages.

Murie, O. J. 1959. Fauna of the Aleutian Islands and Alaska Peninsula. North American Fauna 61: 1–406.

Nelson, E. W. 1887. Report upon natural history collections made in Alaska between the years 1877 and 1881. Arctic series of publications number 3, U.S. Army Signal Service, Washington Government Printing Office. 337 pages.

Robinson, W. B. 1961. Population changes of carnivores in some coyote-control areas. Journal of Mammalogy 42: 510–515.

Rudzinski, D. R., H. B. Graves, A. B. Sargeant, and **G. L. Storm.** 1982. Behavioral interactions of penned red and arctic foxes. Journal of Wildlife Management 46: 877–884.

Schmidt, R. H. 1985. Controlling arctic fox populations with red foxes. Wildlife Society Bulletin 13: 592–594.

Stoudt, J. H. 1971. Ecological factors affecting waterfowl production in Saskatchewan Parklands. Bureau of Sport Fisheries and Wildlife, Resource Publication 99, Washington, D.C. 58 pages.

Swanson, H. 1982. The unknown islands, Cuttlefish VI, Unalaska School District, Unalaska, Alaska. 81 pages.

Received 28 March 1991
Accepted 23 November 1992

First Record for Canada of the Rudd, *Scardinius erythrophthalmus*, and Notes on the Introduced Round Goby, *Neogobius melanostomus*

E. J. Crossman[1], E. Holm[1], R. Cholmondeley[2] and K. Tuininga[3]

[1]Department of Ichthyology and Herpetology, Royal Ontario Museum, Toronto, Ontario M5S 2C6
[2]Ontario Ministry of Natural Resources, P.O Box 605, Brockville, Ontario K6V 5Y8
[3]Ontario Ministry of Natural Resources, P.O. Box 1168, Chatham, Ontario N7M 5L8

Crossman, E. J., E. Holm, R. Cholmondeley and K. Tuininga. 1992. First record for Canada of the Rudd, *Scardinius erythrophthalmus*, and notes on the introduced Round Goby, *Neogobius melanostomus*. Canadian Field-Naturalist 106(2): 206–209.

A European cyprinid, *Scardinius erythrophthalmus*, the Rudd, has been captured in waters connected to the Canadian side of the St. Lawrence River, and specimens of a European gobiid, the Round Goby, *Neogobius melanostomus*, in Canadian waters of the St. Clair River. Both are new to the freshwater fish fauna of Canada.

Key Words: *Scardinius erythrophthalmus*, Rudd, *Neogobius melanostomus*, Round Goby, St. Lawrence River, St. Clair River, first Canadian records.

As now defined by the American Fisheries Society (Kohler and Courtenay 1986), there are 54 species of introduced fishes in Ontario. The newest, for both the Ontario and the Canadian freshwater fish faunas, are the Rudd, *Scardinius erythrophthalmus* (Linnaeus) (Cyprinidae), and the Round Goby, *Neogobius melanostomus* (Pallas) (Gobiidae).

On 24 October 1990 an adult Rudd (Figure 1) was captured by personnel of the Ontario Ministry of Natural Resources (OMNR) in a recently constructed channel in a cattail marsh leading into Thompson's Bay (44°24'10"N, 75°54'30"W), approximately 1 km SW of Cook Point, on the Canadian side of the St. Lawrence River, near Tar and Grenadier islands, Leeds Co., Ontario. The closest records prior to that time were based on individuals captured on the U.S. side of the river, from Grindstone Island downstream to Jacques Cartier State Park, W of Morristown, New York (Klindt 1990). The closest of those was a single specimen captured at Chippewa Point, 11.5 km ENE of Thompson's Bay. Over the period 1989-1990 a total of 11 individuals have been captured on the U.S. side of the river from Grindstone Island downstream to Waddington, New York (Klindt 1991). As a result, this species should be watched for in Ontario as far downstream as Lake St. Lawrence.

The Rudd has been known from two locations tributary to the east side of the Hudson River in New York since the species was introduced there in 1936 (Smith 1985). Klindt (1990) reported, however, that shipments of live bait from the southern U.S. are believed to be responsible for the population in western NY (see Burkhead and Williams 1991). Rudd were also captured by commercial fishermen in the NY portion of Lake Ontario in 1989 (T. Stewart, OMNR, personal communication).

The Rudd is a large, robust, deep-bodied carp or minnow with an oblique (almost vertical) terminal mouth lacking barbels, and a decurved lateral line. In its native habitats it is said to grow to total lengths of 30 to 35 cm and a weight of 1.8 kg. Juvenile Rudd will be easily mistaken for small adults of the native Golden Shiner, *Notemigonus crysoleucas*, and adult Rudd will appear to be oversized, obese Golden Shiners (Figure 1). The following characteristics can be used to separate the two species.

Character	Rudd	Golden Shiner
Lateral line scales	38–42	44–54
Anterior radii on scales	present	absent
Midventral line, pelvic fins to anal fin	keeled but scaled	keeled but not scaled
Gill rakers	9–11	16–19
Iris of eye	yellow or orange, with red spot dorsally	yellow to orange. No red spot
Pharyngeal teeth	in two rows 3,5–5,3 rarely 2,5–5,2	in one row 5–5

The single adult (spent female ?) captured at Thompson's Bay (ROM 60628) was 244 mm TL, and had the following characteristics: 38 and 39 lateral line scales, midventral line keeled and scaled, 11 gill rakers, pharyngeal tooth formula 3,5–5,3, 9 principal dorsal rays, and 11 principal anal rays.

Biologists, Conservation Officers, anglers, and bait dealers should examine fish caught or sold as Golden Shiners in the waters of Lake Ontario and the St. Lawrence River, and remove any Rudd. In

FIGURE 1. Comparison of the introduced Rudd, *Scardinius erythrophthalmus*, (upper ROM 60628) and the native Golden Shiner, *Notemigonus crysoleucas* (lower).

order to avoid damage to populations of native cyprinids by competition and hybridization, the Rudd should not be intentionally or accidently transferred to other waters. On the basis of the history of discovery of specimens on the U.S. side of the river, it is difficult to forecast whether or not the Rudd will become established. It has done so in the Hudson River situation. Burkhead and Williams (1991) provided useful information on the Rudd and its hybrid with the Golden Shiner. They suggested that, as a result of the ability to hybridize, the Rudd may impose a threat to the genetic integrity of the Golden Shiner.

The Round Goby, *Neogobius melanostomus*, native to the Black, Caspian, and Azov seas of southern Europe and Asia has recently been discovered in the St. Clair River. The first published notice of this species in Canadian waters was probably its inclusion in a summary of introduced fishes (Crossman 1991) as one of the species unintentionally introduced in ballast water. More recent details on the biology of this species and its capture in the St. Clair River were provided by Jude et al. (1992). They included specimens from the Canadian side of the river which are in the collection of the University of Michigan Museum of Zoology (UMMZ). Present knowledge of specimens captured in Canadian waters (all Ontario, Lambton County) is as follows: 1) 28 June 1990, St. Clair River, off Sarnia, U.S. angler, 1 specimen, UMMZ 217682; 2) 12 July 1990, St. Clair River, near Sarnia, Canadian angler, 1 specimen, 100 mm TL; 3) 18 July 1990, St. Clair River, at Dow Chemical Plant, 1 specimen, 115 mm TL, UMMZ 218279; 4) 29 August 1990, St. Clair River, Moore Twp., 1 specimen, 100 mm TL, OMNR electrofishing, ROM 60675, Figure 2; 5) 23 September 1990, St. Clair River, near Sarnia, 1 specimen; 6) 5 June 1991, St. Clair River, Moore Twp., near Talfourd Creek, 1 specimen, 65 mm TL, OMNR electrofishing, OMNR specimen.

The specimen illustrated (Figure 2, Number 4 above) was captured in clear water 5–10 m from a natural sandbeach shoreline, in water 0.7–3.0 m deep, flowing at 3–5 knots, with a temperature of 19°C.

FIGURE 2. Comparison of the introduced Round Goby, *Neogobius melanostomus* (upper ROM 60675), and the native Mottled Sculpin, Cottus bairdi

The capture site had a bottom of rubble and sand, and there was some submerged aquatic vegetation.

The Round Goby is a small, cylindrical fish with a prominent head, large eyes, and terminal mouth with large lips. The anterior nostrils are tubed but the tubes do not reach the upper lip. The top of the head behind the eyes and the body are covered with small cycloid scales. There are two dorsal fins, the anterior with 5–7 spines, the other with one spine and 13–16 soft rays. There is a prominent black spot near the base of the rear portion of the spiny-rayed dorsal fin. The caudal fin is rounded. The most distinctive feature is the suctorial disk formed by the fusion of the pelvic fins.

The Round Goby captured by electrofishing (Figure 2, ROM 60675) had the following characteristics: Body with four dark, irregular, lateral blotches, 3–5 scales in width; back with three wide, dark saddles; dorsal fins VI+I15 (last ray split to base), fin with black spot on membrane between spines IV and VI; pelvic fin I5, with complete frenum (anterior membrane joining the left and right pelvic fins) and basal membrane creating a pocket; pectoral fin with 18 rays, a pupil-sized, black spot near upper edge of the lateral surface of the scaled fin base, and a larger, dark blotch or bar in the same location on the medial surface; irregular rows of conical teeth in upper and lower jaws; 50 lateral scale rows; no lateral line.

In Canadian waters the Round Goby could be mistaken for one of the native sculpins (Figure 2). The Round Goby can, however, be distinguished from them by the pelvic suctorial disk, the obvious scales on the body, and the prominent black spot on the spiny dorsal fin.

In its native habitat the Round Goby is found in the sea and the lower to middle reaches of rivers, in brackish or freshwater. It is said (Whitehead et al. 1986) to spawn in slightly brackish areas, from April to September. The discovery of young-of-the-year on the U.S. side of the river indicates that spawning took place there in full freshwater.

This goby has been taken in much larger numbers on the U.S. side of the river (Jude et al. 1992). Those collections included young-of-the-year and two other year classes, indicating the species is established and reaching dense populations in certain locations (D. Jude, personal communication). A potential threat posed by this introduced species is obvious in that numbers of indigenous species have declined in areas where the gobies have become abundant (G. Smith, personal communication).

Another goby, *Proterorhinus marmoratus*, the Tubenose Goby, has been taken on the U.S. side of the St. Clair River (Jude et al. 1992). The two gobies can be distinguished by the following characteristics:

CHARACTER	*Neogobius melanostomus*	*Proterorhinus marmoratus*
Pattern of spiny dorsal fin	large posterior black spot, no oblique, black lines	no such spot, prominent, oblique, black lines
Body pattern	4 or 5 dark but irregular blotches	5 broad, dark, oblique bars
Anterior nostril	tube not reaching upper lip	tube reaching to, or beyond, lower lip
Maximum TL	to 25 cm	to 11 cm

It is most likely that both these gobies have, like several other newly discovered species, been introduced unintentionally with ballast water released by ships originating in Europe.

It is strange that 31 Tubenose Gobies have been captured on the U.S. side of the St. Clair River (Jude et al. 1992) but to date, none have been reported from the Canadian side. All fishes resembling sculpins should be closely examined to watch for the predictable spread of the Tubenose Goby, and to document any increase in numbers of the Round Goby.

Acknowledgments

We express our thanks to D. Dodge, T. Stewart, and other personnel of the OMNR that have been involved in the collection and recognition of specimens worthy of special attention, or in making new records known to us. G. Smith and D. Jude of Michigan kindly made available more recent information on gobies in the St. Clair River. R. Winterbottom provided helpful advice on writing about gobies. The photographs were taken by Brian Boyle of the Royal Ontario Museum.

Literature Cited

Burkhead, N. M., and **J. D. Williams.** 1991. An intergeneric hybrid of a native minnow, the golden shiner, and an exotic minnow, the rudd. Transactions of the American Fisheries Society 120(6): 781–795.

Crossman, E. J. 1991. Introduced freshwater fishes: A review of the North American perspective with emphasis on Canada. Canadian Journal of Fisheries and Aquatic Sciences 48(Supplement 1): 46–57.

Jude, D. J., R. H. Reider, and **G. R. Smith.** 1992. Establishment of Gobiidae in the Great Lakes Basin. Canadian Journal of Fisheries and Aquatic Sciences 92(2): 416–421.

Klindt, R. 1990. Distribution of rudd in the St. Lawrence River. Report to the Great Lakes Fishery Commission, St. Lawrence River Subcommittee: 71–72.

Klindt, R. 1991. Rudd in the St. Lawrence River: 1989-1990. Report to the Great Lakes Fishery Commission, St. Lawrence River Subcommittee. 2 pages.

Kohler, C. C., and **W. R. Courtenay, Jr.** 1986. American Fisheries Society position on introduction of aquatic species. Fisheries 11(2): 39–42.

Smith, C. L. 1985. The inland fishes of New York State. New York State Department of Environmental Conservation. Albany, New York. 522 pages.

Whitehead, P. J. P., M.-L.Bauchot, J.-C. Hureau, J. Nielson, and **E. Tortonese.** *Editors.* 1986. Fishes of the North-eastern Atlantic and the Mediterranean. Volume 3, UNESCO, Paris, France: 1013–1473.

Received 26 March 1991
Accepted 26 March 1992

Comparison Between Urban and Rural Bird Communities in Prairie Saskatchewan: Urbanization and Short-term Population Trends

NAVJOT S. SODHI

Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan S7N OWO
Present address: Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9

Sodhi, Navjot S. 1992. Comparison between urban and rural bird communities in prairie Saskatchewan: urbanization and short-term population trends. Canadian Field-Naturalist 106(2): 210–215.

I censused 12 1-km transects, six in and six outside Saskatoon, Saskatchewan, once each in May and June, 1988 through 1990. Bird fauna in the city was nearly as diverse as the nearby rural habitat type. House Sparrow (*Passer domesticus*) was the most abundant urban species. Horned Lark (*Eremophila alpestris*) was the most abundant rural species in May 1988, while Western Meadowlark (*Sturnella neglecta*) was the most abundant rural species in May 1989 and 1990 and in June of all three years. Most of the urban bird fauna consisted of non-grassland and introduced bird species. The only grassland species which was relatively common in the city was Clay-colored Sparrow (*Spizella pallida*). Some non-grassland and introduced species such as House Sparrow, American Robin (*Turdus migratorius*), House Wren (*Troglodytes aedon*), and Yellow Warbler (*Dendroica petechia*) have also invaded rural habitat type. Bird diversity did not differ statistically between the urban and rural habitat types, but bird abundance was significantly higher in the city in May. Overall, bird abundance declined from 1988 to 1990 in both habitat types. Of the species recorded in all three years, one-third to one-half steadily declined in numbers in both habitat types. The species that showed steady declines (33% to 91%) in populations in either habitat type and either or both months were: Rock Dove (*Columba livia*), Horned Lark, American Crow (*Corvus brachyrhynchos*), Clay-colored Sparrow, Savannah Sparrow (*Passerculus sandwichensis*), Western Meadowlark, Brewer's Blackbird (*Euphagus cyanocephalus*), and House Sparrow.

Key Words: Urban, rural, prairie bird communities, bird diversity, bird abundance, population declines, Saskatchewan.

Recently, concern has been raised over the status of prairie birds (De Smet and Conrad 1991, Wershler et al. 1991). However, other than analyses of the Breeding Bird Survey data (e.g., Erskine 1978), few specific studies have been done to determine community structure and population trends of prairie birds. The objectives of this research were to: (1) compare bird abundance and diversity between urban and rural habitat types in and around Saskatoon; (2) examine the extent of bird fauna overlap between these two habitat types; and (3) determine population trends of birds over three years in both these habitat types.

Methods

I surveyed 12 randomly selected 1-km transects, six in and six outside Saskatoon, Saskatchewan (52°07'N, 106°38'W). The rural transects were between 1.2 and 4.5 km from the city limits. Four were on cultivated areas and two were on native grasslands. All urban transects were roads passing through residential areas (developed between 1920 and 1960). Three urban transects included parts of at least one park. All rural transects were at least 100 m away from nearest grid road or different habitat. The cultivated fields (wheat) on which four rural transects were done had native grasslands on at least one side and other wheat fields on the other sides. Native grasslands on which two rural transects were done had wheat fields on three sides and native grassland on the fourth side. Bird species recorded on cultivated fields were similar, although less abundant, than those recorded on the grassland transects. Therefore, I combined data from the cultivated field and grassland transects.

Each transect was surveyed twice, once in the last ten days of May and again in the last ten days of June, 1988 through 1990. These months were chosen as survey months because some summer migrants are still in Saskatoon in late May but by the end of June only breeding birds remain. Censuses were made within the first four daylight hours of good weather ($\leq$ 10% cloud cover, $\leq$ 15 km/hr wind speed). On average, I took 12.5 $\pm$ 1.62 and 12.7 $\pm$ 2.14 min to complete an urban and rural transect, respectively. Birds seen or heard within 90 m of each side of the transects were counted. Preliminary surveys of the study area showed that while I could detect birds from more than 90 m of rural transects, I could not detect birds from more than 90 m of urban transects. Therefore, to make methods comparable between two habitat types, I counted birds within 90 m of both rural and urban transects. This counting method may have underestimated bird abundance on rural transects.

I grouped all recorded birds into three categories (Table 1): grassland species (cf. Knoff 1988 and McNicholl 1988), non-grassland species, and intro-

TABLE 1. Three groups of bird species encountered in and around Saskatoon.

Grassland birds
- Swainson's Hawk (*Buteo swainsonii*)
- Marbled Godwit (*Limosa fedoa*)
- Horned Lark (*Eremophila alpestris*)
- Clay-colored Sparrow (*Spizella pallida*)
- Vesper Sparrow (*Pooecetes gramineus*)
- Savannah Sparrow (*Passerculus sandwichensis*)
- Baird's Sparrow (*Ammodramus bairdii*)
- Western Meadowlark (*Sturnella neglecta*)

Non-grassland birds
- Red-tailed Hawk (*Buteo jamaicensis*)
- American Kestrel (*Falco sparverius*)
- Black-bellied Plover (*Pluvialis squatarola*)
- Killdeer (*Charadrius vociferus*)
- Willet (*Catoptrophorus semipalmatus*)
- Franklin's Gull (*Larus pipixcan*)
- Ring-billed Gull (*L. delawarensis*)
- California Gull (*L. californicus*)
- Mourning Dove (*Zenaida macroura*)
- Hairy Woodpecker (*Picoides villosus*)
- Eastern Kingbird (*Tyrannus tyrannus*)
- Tree Swallow (*Tachycineta bicolor*)
- Barn Swallow (*Hirundo rustica*)
- Black-billed Magpie (*Pica pica*)
- American Crow (*Corvus brachyrhynchos*)
- Black-capped Chickadee (*Parus atricapillus*)
- Red-breasted Nuthatch (*Sitta canadensis*)
- House Wren (*Troglodytes aedon*)
- Swainson's Thrush (*Catharus ustulatus*)
- American Robin (*Turdus migratorius*)
- Brown Thrasher (*Toxostoma rufum*)
- Cedar Waxwing (*Bombycilla cedrorum*)
- Loggerhead Shrike (*Lanius ludovicianus*)
- Red-eyed Vireo (*Vireo olivaceus*)
- Yellow Warbler (*Dendroica petechia*)
- Chipping Sparrow (*Spizella passerina*)
- White-throated Sparrow (*Zonotrichia albicollis*)
- Red-winged Blackbird (*Agelaius phoeniceus*)
- Yellow-headed Blackbird (*Xanthocephalus xanthocephalus*)
- Brewer's Blackbird (*Euphagus cyanocephalus*)
- Common Grackle (*Quiscalus quiscula*)
- Brown-headed Cowbird (*Molothrus ater*)
- Northern Oriole (*Icterus galbula*)
- Red Crossbill (*Loxia curvirostra*)

Introduced birds
- Gray Partridge (*Perdix perdix*)
- Rock Dove (*Columba livia*)
- House Sparrow (*Passer domesticus*)

duced species (introduced into North America by man). Throughout the text, I refer to bird diversity to indicate the number of bird species and bird abundance or number to indicate the number of individuals recorded.

Results

In May 1988-1990, I recorded 42 bird species (Table 2). House Sparrow was the most abundant urban species. On the urban transects, 21, 13, and 16 species were recorded in 1988, 1989, and 1990, respectively. Outside the city, Horned Lark was the most abundant species in 1988, with Western Meadowlark being most abundant in 1989 and 1990 (Table 2). I found 27, 11, and 11 species during 1988, 1989, and 1990, respectively, on the rural transects. Combining data from different years, about 31% (13) species were common to both habitat types during May. Of these rural/urban species, only two were grassland species (Clay-colored Sparrow and Western Meadowlark). The remaining included non-grassland and introduced birds (e.g., Black-billed Magpie, American Crow, American Robin, and House Sparrow).

For May, bird diversity did not differ significantly among years on the urban transects ($\chi^2 = 2.0$, df = 2, $p > 0.20$), but did differ significantly on the rural transects ($\chi^2 = 10.4$, df = 2, $p < 0.01$). Bird number declined significantly from 1988 to 1990, both in the urban ($\chi^2 = 67.9$, df = 2, $p < 0.001$) and rural habitats types ($\chi^2 = 135.4$, df = 2, $p < 0.001$). Between the two habitat types, bird diversity did not differ significantly ($\chi^2 = 1.8$, df = 2, $p > 0.20$), but more individuals were recorded in the city ($\chi^2 = 27.0$, df = 2, $p < 0.001$).

In May, on the urban transects, I encountered ten species in all three years. Two of these showed a steady decline in number, none increased in number, the population of one species remained stable, and other species showed various population trends (Table 2). The two steadily declining species were House Sparrow (declined by 50%, 1988-1990) and Rock Dove (46%). On the rural transects, nine species were recorded in all years, four of these steadily declined in abundance, none increased in number, and other species showed various population trends (Table 2). Four species that showed steady declines were Horned Lark (75%), Savannah Sparrow (67%), Brewer's Blackbird (66%), and Western Meadowlark (47%).

In June 1988-1990, I recorded 34 species of birds (Table 3). House Sparrow again was the most abundant urban species. The number of species encountered were 16, 16, and 14 in 1988, 1989, and 1990, respectively, on the urban transects. Western Meadowlark was the most abundant rural species in this month. Fifteen species were recorded in all three years on the rural transects. Combining data from different years, 38% (13) species were common to both habitat types, most of which were non-grassland or introduced species.

Recorded bird numbers in June declined significantly from 1988 to 1990 in the urban ($\chi^2 = 34.8$, df = 2, $p < 0.001$) as well as the rural ($\chi^2 = 36.7$, df = 2, $p < 0.001$) habitat type. Bird numbers ($\chi^2 = 0.1$, df = 2, $p > 0.20$) and diversity ($\chi^2 = 0.7$, df = 2, $p > 0.20$) did not differ significantly between the two habitat types in June.

TABLE 2. Urban and rural bird populations in Saskatoon area in May (1988-1990). Data presented as total number of individuals recorded of each species.

	Urban			Rural		
Species	1988	1989	1990	1988	1989	1990
Swainson's Hawk	–	–	–	1	–	–
Red-tailed Hawk	–	–	–	3	–	–
American Kestrel	–	–	1	–	–	–
Marbled Godwit	–	–	–	1	–	–
Black-bellied Plover	–	–	–	–	–	6
Killdeer	–	–	–	2	–	–
Franklin's Gull	46	–	–	–	–	–
Ring-billed Gull	13	31	10	7	–	–
California Gull	1	1	–	–	–	–
Gray Partridge	–	–	–	4	–	–
Mourning Dove	–	–	–	1	–	–
Rock Dove	89	64	48	7	–	–
Eastern Kingbird	–	–	–	1	–	–
Horned Lark	–	–	–	51	20	13
Tree Swallow	1	–	–	4	–	–
Barn Swallow	–	–	–	6	–	–
Black-billed Magpie	9	2	5	3	3	1
American Crow	12	5	6	8	2	–
Black-capped Chickadee	1	1	–	–	–	–
Red-breasted Nuthatch	2	–	–	–	–	–
House Wren	4	1	1	1	–	–
American Robin	15	32	28	–	1	–
Cedar Waxwing	–	–	2	3	–	–
Loggerhead Shrike	–	–	–	1	–	–
Red-eyed Vireo	1	–	–	–	–	–
Yellow Warbler	20	–	9	1	–	–
Clay-colored Sparrow	24	1	6	17	4	5
Chipping Sparrow	22	8	30	–	–	–
White-throated Sparrow	1	–	4	–	–	–
Savannah Sparrow	–	–	–	24	15	8
Vesper Sparrow	–	–	–	20	1	3
Baird's Sparrow	–	–	–	1	–	–
House Sparrow	187	152	93	5	1	3
Western Meadowlark	1	1	1	38	28	20
Red-winged Blackbird	–	–	1	–	–	–
Yellow-headed Blackbird	–	–	–	4	–	–
Brewer's Blackbird	4	4	–	38	16	13
Common Grackle	1	–	–	–	–	–
Brown-headed Cowbird	–	–	–	1	1	2
Northern Oriole	1	–	–	–	–	–
Red Crossbill	–	–	3	–	–	–
American Goldfinch	–	–	–	–	–	3
Total	455	303	248	253	92	72

On the urban transects in June, 11 species were recorded in all three years, the numbers of three species steadily declined and no species showed steady increase in abundance (Table 3). On the rural transects, seven species were encountered in all three years, four steadily declined, one remained unchanged, and no species increased in abundance (Table 3). The species that showed steady declines in abundance on the urban transects were House Sparrow (declined by 45%, 1988-1990), Clay-colored Sparrow (91%), and Rock Dove (83%). The species showing steady declines in the rural area were Western Meadowlark (51%), Savannah Sparrow (33%), Horned Lark (50%), and American Crow (80%).

Between the two survey months, bird diversity did not differ significantly, and bird numbers differed significantly only outside the city ($\chi^2 = 13.0$, df = 2, $p < 0.01$).

Discussion

This study indicates that bird fauna of Saskatoon is nearly as diverse as that of nearby rural habitat type. Studies from other habitats report more bird

TABLE 3. Urban and rural bird populations in Saskatoon area in June (1988-1990). Data presented as total number of individuals recorded of each species.

	Urban			Rural		
Species	1988	1989	1990	1988	1989	1990
Swainson's Hawk	–	–	–	–	–	1
Red-tailed Hawk	–	–	–	–	1	–
American Kestrel	–	1	–	–	–	–
Killdeer	–	–	–	1	1	3
Willet	–	–	–	–	–	1
Franklin's Gull	–	–	–	20	–	–
Ring-billed Gull	11	22	16	11	–	1
Gray Partridge	–	–	–	–	–	1
Rock Dove	126	66	22	5	–	–
Hairy Woodpecker	–	1	–	–	–	–
Horned Lark	–	–	–	30	25	15
Eastern Kingbird	–	–	–	–	1	1
Tree Swallow	4	–	–	–	–	–
Barn Swallow	–	–	–	2	–	–
Black-billed Magpie	7	2	8	4	1	–
American Crow	12	1	12	5	3	1
Black-capped Chickadee	3	–	–	–	7	–
House Wren	11	1	4	–	1	–
Swainson's Thrush	–	2	1	–	–	–
Brown Thrasher	1	–	–	–	–	–
American Robin	20	17	19	1	–	–
Cedar Waxwing	6	20	15	–	–	–
Yellow Warbler	14	12	13	–	–	–
Clay-colored Sparrow	22	8	2	8	10	4
Chipping Sparrow	27	19	20	–	1	–
Savannah Sparrow	–	–	–	15	13	10
Vesper Sparrow	–	–	–	7	–	1
House Sparrow	233	183	129	–	4	3
Western Meadowlark	–	–	1	35	30	17
Red-winged Blackbird	–	–	1	–	–	–
Brewer's Blackbird	8	2	–	32	13	22
Common Grackle	1	–	–	1	–	1
Brown-headed Cowbird	–	–	–	–	3	–
American Goldfinch	–	1	–	–	–	–
Total	506	358	263	177	114	82

species in the nearby native rather than urban habitats (e.g., Emlen 1974; Rosenberg et al. 1987; but see Aldrich and Coffin 1980). The results of these studies are not directly comparable to my study because I combined data from cultivated transects with those from grassland (native habitat) transects.

I found that the bird fauna was significantly more abundant in the city in May as compared to rural habitat type but not in June. Previous studies also report higher bird abundance in urban habitats when compared to nearby native habitat (Aldrich and Coffin 1980; Bessinger and Osborne 1982; Rosenberg et al. 1987; Mills et al. 1989). These studies suggest that urban habitat type is probably more rich, or diverse, or both, than the native habitat.

House Sparrow has been recorded as the most abundant species in many cities, e.g. Legnica, Poland (Tomialojc 1970); Tornio, Finland (Huhtalo 1978); and Tucson, USA (Emlen 1974; Rosenberg et al. 1987). The urban fauna of Saskatoon consisted mainly of non-grassland and introduced bird species. Savard (1978) and Lancaster and Rees (1979) also reported urban bird fauna dominated mainly by non-native species in Toronto and Vancouver, respectively. Aldrich and Coffin (1980) and Dance (1986) documented that with urban development native bird species are replaced by non-native species.

The non-grassland and introduced birds have also invaded rural habitat type (Tables 2 and 3). The only grassland species which has appeared to successfully colonize Saskatoon in high numbers is Clay-colored Sparrow. Urbanization of Clay-colored Sparrow has been reported previously from the Canadian prairies (McNicholl 1977). I found urban abundance of Clay-colored Sparrows was usually higher than the rural abundance (Tables 2 and 3). Previously, Wilson and

Belcher (1989) recorded a significant correlation between Clay-colored Sparrow population and introduced Eurasian plant species abundance in Manitoba. Another reason for urban prolification of this species may be its preference for nesting in shrubs (Knapton 1978). Such nesting sites are amply available in urban areas.

Other than Clay-colored Sparrow, I recorded one individual of another grassland species i.e., Western Meadowlark, almost every year on an open area in the city. Ground nesting prairie species may not successfully invade urban habitats because of many potential predators such as dogs and cats (see Churcher and Lawton 1987). Other factors which might affect colonization of rural birds in urban habitats include food preference and availability, habitat structure (e.g., plant species richness), territoriality, and water availability (Emlen 1974; Lancaster and Rees 1979; Rotenberry and Wiens 1980).

Bird numbers declined from 1988 to 1990 in both months, while in May bird diversity declined from 1988 to 1989 and then remained unchanged. Of species that were recorded in all three years, 30% and 27% showed declines in the urban areas in May and June, respectively. Forty-four percent and 57% of such rural species in May and June, respectively, declined in abundance. One previous analysis of the Breeding Bird Surveys showed no steady trend of increase or decrease of passerines on the Canadian prairie provinces (1972-1976; Gollop 1978). While another analysis of the Breeding Bird Surveys in the southern Canadian prairies (1970-1975; Erskine 1978) indicated that four species increased in numbers steadily (Gadwall *Anas strepera*, Sora *Porzana carolina*, Common Yellowthroat *Geothlypis trichas*, and Yellow-headed Blackbird) while one species steadily decreased in abundance (Marbled Godwit). However, Erskine (1978) reported no steady decline or increase for the species showing declines in my study area.

Robbins et al. (1986) by analysing North American Breeding Bird Survey data (1967-1979) reported apparent stable populations of Savannah Sparrow, Horned Lark, and Brewer's Blackbird. Rock Dove was generally decreasing in abundance in western North America, but increasing both in eastern and central North America. House Sparrow populations in western North America were also declining. However, from 1967-1979, populations of Clay-colored Sparrow significantly increased in Saskatchewan, while that of Western Meadowlark decreased. Recently, Graham (1990) suggested that there has been a drastic decrease in the population of Western Meadowlark in North America.

In summary, the results of my study show steady population declines for some prairie birds over three years. Because of small number of transects sampled and only three years of data collection, these data cannot be considered indicative of long-term population declines of prairie birds. However, results of the study should prompt long-term specific studies monitoring prairie bird populations.

Acknowledgments

This study was supported by a Natural Sciences and Engineering Research Council of Canada grant to Lynn W. Oliphant and a University of Saskatchewan graduate scholarship to me. I thank Martin K. McNicholl, Daniel F. Brunton, Lynn W. Oliphant, and an anonymous reviewer for making comments on this manuscript.

Literature Cited

Aldrich, J. W., and **R. W. Coffin.** 1980. Breeding bird populations from forest to suburbia after thirty-seven years. American Birds 34: 3–7.

Bessinger, S. R., and **D. A. Osborne.** 1982. Effects of urbanization on avian community organization. Condor 84: 75–83.

Churcher, P. B., and **J. H. Lawton.** 1987. Predation by domestic cats in an English village. Journal of Zoology (London) 212: 439–455.

Dance, K. W. 1986. Avifauna of an urbanizing environment in southern Ontario, 1921-1982. Ontario Birds 4: 22–29.

De Smet, K. D., and **M. P. Conrad.** 1991. Management and research needs for Baird's Sparrows and other grassland species. Pages 83–86 *in* Proceedings of the second endangered species and prairie conservation workshop, *Edited by* G. Holroyd, G. Burns, and H. C. Smith. Provincial Museum of Alberta Natural History, Occasional Paper Number 15.

Emlen, J. T. 1974. An urban bird community in Tuscon, Arizona: derivation, structure, regulation. Condor 76: 184–197.

Erskine, A. J. 1978. First ten years of the co-operative breeding bird survey in Canada. Canadian Wildlife Service Report Series Number 42.

Huhtalo, H. 1978. Differential changes in bird community structure with urbanization: a study in central Finland. Ornis Scandinavica 9: 94–100.

Gollop, J. B. 1978. Changes in songbird populations since the mid-1940's in the prairie provinces. Pages 78–103 *in* Nature and change on the Canadian plains, *Edited by* W. A. Davies. Canadian Plains Research Center, Regina.

Graham, F., Jr. 1990. 2001: birds that won't be with us. American Birds 44: 1074–1081, 1194–1199.

Knapton, R. W. 1978. Breeding ecology of the Clay-colored Sparrow. Living Bird 17: 137–158.

Knoff, F. L. 1988. Conservation of steppe birds in North America. Pages 27–41 *in* Ecology and Conservation of grassland birds, *Edited by* P. D. Goriup. International Council for Bird Preservation, Technical Publication Number 7.

Lancaster, R. K., and **W. E. Rees.** 1979. Bird communities and the structure of urban habitats. Canadian Journal of Zoology 57: 2358–2368.

McNicholl, M. K. 1977. A habitat note on Clay-colored Sparrows in Edmonton. Edmonton Naturalist 5: 30–31.

McNicholl, M. K. 1988. Ecological and human influences on Canadian populations of grassland birds. Pages 1–25 *in* Ecology and conservation of grassland birds, *Edited by* P. D. Goriup. International Council for Bird Preservation, Technical Publication Number 7.

Mills, G. S., J. B. Dunning, Jr., and **J. M. Bates.** 1989. Effects of urbanization on breeding bird community structure in southwestern desert habitats. Condor 91: 416–428.

Robbins, C. S., D. Bystrack, and **P. H. Geissler.** 1986. The breeding bird survey: its first fifteen years, 1965-1979. U.S. Fish and Wildlife Service Resource Publication 157.

Rosenberg, K. V., S. B. Terril, and **G. H. Rosenberg.** 1987. Value of suburban habitats to desert riparian birds. Wilson Bulletin 99: 642–654.

Rotenberry, J. T., and **J. A. Wiens.** 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. Ecology 61: 1228–1250.

Savard, J.–P. 1978. Birds in metropolitan Toronto: distribution, relationships with habitat features and nesting sites. M.Sc. Thesis, University of Toronto, Toronto.

Tomialojc, L. 1970. Quantitative studies on the synanthropic avifauna of Legnica and its environs. Acta Ornithologica 12: 293–392.

Wershler, C., W. W. Smith, and **C. Wallis.** 1991. Status of the Baird's Sparrow in Alberta-1987/1988 update with notes on other grassland sparrows and Sprague's Pipit. Pages 87–89 *in* Proceedings of the second endangered species and prairie conservation workshop, *Edited by* G. L. Holroyd, G. Burns, and H. C. Smith. Provincial Museum of Alberta Natural History, Occasional Paper Number 15.

Wilson, S. D., and **J. W. Belcher.** 1989. Plant and bird communities of native prairie and introduced Eurasian vegetation in Manitoba, Canada. Conservation Biology 3: 39–44.

Received 28 May 1991
Accepted 9 March 1992

Northward Invading Non-native Vascular Plant Species in and Adjacent to Wood Buffalo National Park, Canada

Ross W. Wein,[1] Gerold Wein,[2] Sieglinde Bahret[2] and William J. Cody[3]

[1]Canadian Circumpolar Institute and Departments of Botany and Forest Science, University of Alberta, Edmonton T6G 2H1

[2]Institut fuer Biologie I, Lehrbereich Spezielle Botanik, Auf der Morgenstelle 1, Tuebingen University, 7400 Tuebingen, Germany

[3]Centre for Land and Biological Resources Research, Agriculture Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6

Wein, Ross W., Gerold Wein, Sieglinde Bahret, and William J. Cody. 1992. Northward invading non-native vascular plant species in and adjacent to Wood Buffalo National Park, Canada. Canadian Field-Naturalist 106(2): 216–224.

A survey of the non-native vascular plant species in Wood Buffalo National Park, Canada's largest forested National Park, documented their presence and abundance in key locations. Most of the fifty-four species (nine new records) were found in disturbed sites including roadsides, settlements, farms, areas of altered hydrological regimes, recent burns, and intensive bison grazing. Species that have increased most in geographic area and abundance in recent years include *Agropyron repens, Bromus inermis, Chenopodium album, Melilotus* spp., *Trifolium* spp., *Plantago major, Achillea millefolium, Crepis tectorum* and *Sonchus arvensis*. An additional 20 species, now common in the Peace River and Fort Vermilion areas, have the potential to invade the Park if plant communities are subjected to additional stress as northern climates are modified by the greenhouse effect and as other human-caused activities disturb the vegetation. It is recommended that permanent plots be located in key locations and monitored for species invasion and changing abundances as input to management plans.

Key Words: Wood Buffalo National Park, invading plants, non-native plants, weeds, disturbance, climate change.

Non-native plant species, primarily from Europe, moved with agricultural development into southern Canada and through the twentieth century, have dispersed northward via railway and road systems. In the last few decades, northern development has occurred at an unprecedented rate with hydroelectric, mineral and petroleum development, as well as increased urbanization, disturbing large areas of the landscape that are connected with north-south transportation corridors. Now scientists are gathering mounting evidence that these disturbed areas and avenues of invasion will become more effective with climate changes due to the greenhouse effect, since this would lead to warmer conditions at high latitudes of the northern hemisphere (e.g., see review by Roots 1989).

National parks are to maintain "...a natural environment essentially unaltered by human activity" (Parks Canada 1983), but there have been important changes in park vegetation over time. This is especially true for small national parks where the surrounding ecosystems are heavily modified through agricultural or urban influences. In these small parks, there is continuing pressure from organisms to invade and to change the natural ecosystem dynamics. For example, in Fundy National Park, New Brunswick, 130 species or 22% of the total vascular plant species are thought to be introduced (Burzynski et al. 1986). The small western Canadian park of Elk Island National Park, contains 57 non-native vascular plant species, which is 14.5% of the total flora of 393 species (Williams 1987; Achuff 1991). The development of townsites and major transportation corridors (railroads, highways and pipelines) has changed the biodiversity of the smaller Rocky Mountain national parks; in Yoho National Park, 87 species or 13.2% of the flora are non-native (Kuchar 1978; Achuff 1991) and in Mt. Revelstoke and Glacier National Park, 69 species or 12.3% of the flora are non-native (Achuff and Dudynsky 1984, Achuff 1991). In the larger Rocky Mountain national parks, non-native plants comprise 9.0% of the flora of Jasper National Park (69 of 773 species) and 8.5% of the flora of Banff National Park (71 of 835 species) (Achuff and Corns 1982; Achuff 1991). Present Canadian Parks policy is to prevent future introductions of non-native species and to remove those species already established (Parks Canada 1983); but, the removal of introductions is not easily accomplished because many are incidental to other continuing human activity.

Non-native species are also moving northward with human activity to enter National Parks in the boreal forest zone. Beckett (1959) for example, recorded 76 vascular plant species (native and non-native) that were growing in the disturbed areas of Churchill, Manitoba which is located at the arctic tundra — boreal forest ecotone at 58°46'N latitude. Staniforth and Scott (1991) documented an increase

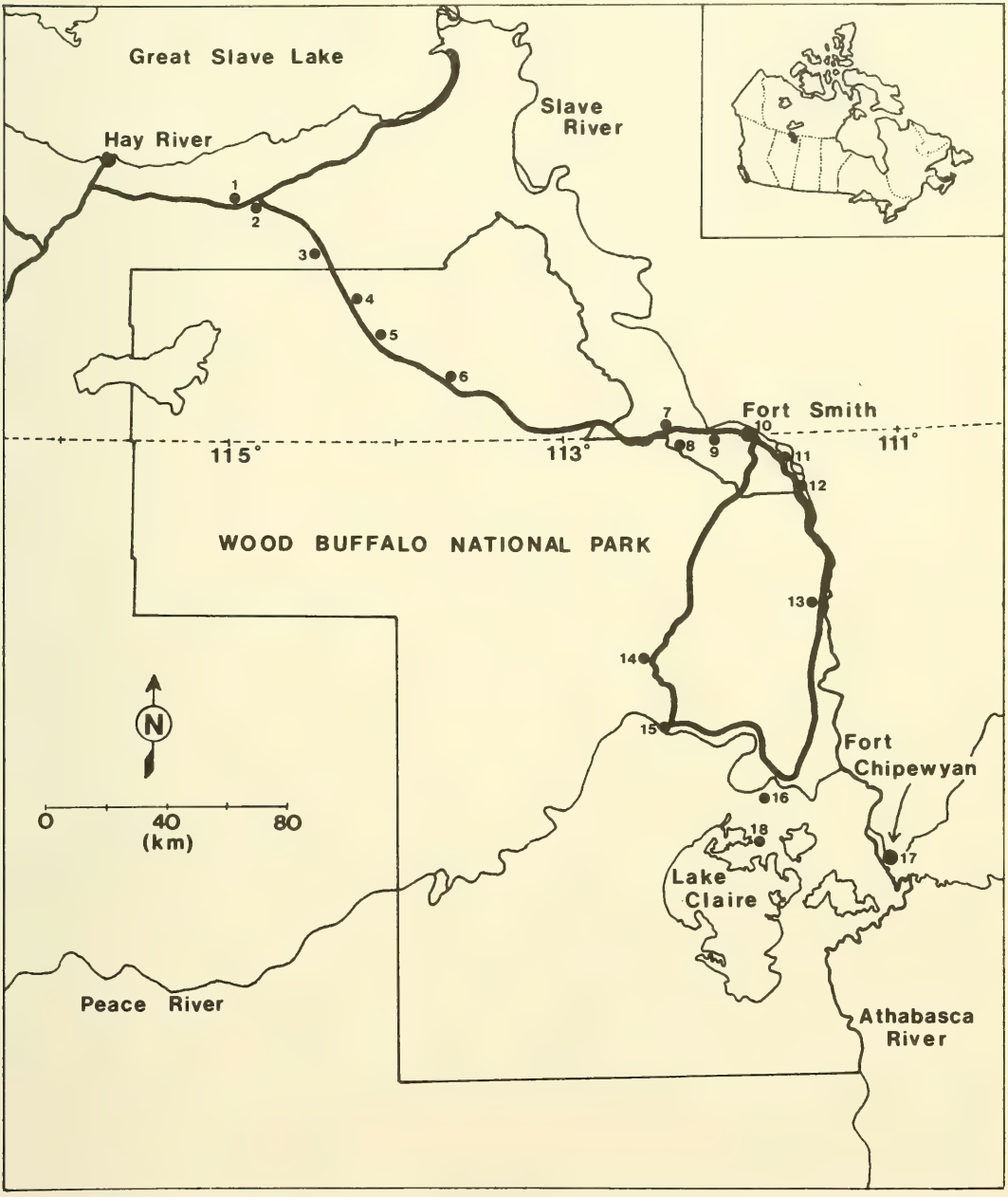


FIGURE 1. Location of the 18 collection sites in Wood Buffalo National Park at about 60°N latitute (dotted line). See Table 1 for specific site characteristics.

in the number of species to 106 and an increase in abundance of many species over the past 30 years. These populations are continuously augmented by propagules through railway shipments of grain from the prairies to the elevators. In the more boreal zone of Central Quebec and Labrador (centered on 54°N latitude), Hustich (1971, 1972) estimated that about 100 species or about 15% of the vascular plant flora was introduced. Most of the non-native species were of temperate origin and tended to be restricted to northern microhabitats that were heavily disturbed by roads, railways, communities and industry.

For the most part, non-native species have difficulty invading native vegetation unless communities are stressed, although some species, such as *Centaurea maculosa* (Tyser and Key 1988) and *Linaria dalmatica* (Achuff 1991), have invaded apparently undisturbed communities in southern national parks. To date there is no evidence of non-native species invading undisturbed northern boreal forest and tundra vegetation (Beckett 1959; Staniforth and Scott 1991).

There have been no recent evaluations of non-native vascular plants in conservation areas of northwest Canada; therefore, the objective of this study was to document the status of non-native vascular plants in Wood Buffalo National Park and in the nearby settlements such as Fort Smith and Fort Chipewyan, to serve as a benchmark against which future introductions could be recognized.

Methods

Study area description

Wood Buffalo National Park is approximately 44 800 km^2 and stretches almost 300 km from latitude 58°05'N to latitude 60°32'N (Figure 1). The Park includes part of the Birch and Caribou Mountains that range up to 1000 m in altitude, but most of the Park lies between 200 and 300 m a.s.l. The Park is forested, except for the Peace-Athabasca Delta, at 5040 km^2, which is one of the largest freshwater deltas in the world.

Many human factors may have led to the invasion of non-native vascular plants into the Park. Human habitation has been documented archaeologically for several thousand years (Stephenson 1986) and the Euro-Canadian fur trade has been active in the area for more than two centuries (Potyondi 1979). More importantly, over time there has been an increase in the quantity of materials transported through the Athabasca and Slave River systems. In the summers of 1925-1928 approximately 6600 bison were shipped from Wainwright Buffalo Park in southern Alberta to Hay Camp in the Park. The period of greatest transport volume occurred during the Second World War when equipment and supplies for the Norman Wells oil refinery and Canol pipeline development were unloaded at Fort Fitzgerald and transported overland to Bell Rock in order to by-pass the dangerous rapids on the Slave River near present-day Fort Smith. Fort Smith became the administrative centre of the Northwest Territories and the Roman Catholic Church operated a school, hospital, and church. Food for this settlement was supplied locally, particularly by the St. Bruno Mission Farm (established 1910, closed about 1930) within Park boundaries near the salt flats west of Fort Smith. In the 1960s, an all-weather road system was built from Hay River to Fort Smith and through the central and eastern portion of the Park. The construction of the W. A. C. Bennett Dam on the Peace River in British Columbia in the late 1960s led to an altered hydrological regime of the Peace-Athabasca Delta. If the invasion of the non-native species can be aided by fire, then the 1979-1981 fires that burned more than 20% of the Park could also be a significant event.

History of Collecting

Porsild and Cody (1980) have included a general history of collecting in the Northwest Territories which includes references to collections from the northern parts of Wood Buffalo National Park. Collections of particular value to the present study have been recorded by Raup (1935, 1936, 1946), Groh (1937, 1949), Cody (1956, 1961, 1978), and Porsild and Cody 1968, while generalized floras bringing many collections together were produced by Porsild and Cody (1968, 1980) and Moss (1983).

Collections

Vascular plant collections were made during August 1986, and during July and August of 1987 and 1988 in key locations where non-native species would likely be found, and, if not already present, would likely be key areas for future establishment. The road systems, including Highway #5 which begins near Hay River (kilometre post 0) and ends at Fort Fitzgerald and the Wood Buffalo National Park Loop Road, were examined because road building and maintenance machinery as well as normal road travel readily move propagules. Collections were also made around the communities of Fort Smith, Peace Point and Fort Chipewyan, on farms near Fort Smith and near former farm building sites on the St. Bruno Mission Farm because weeds could have been transported from southern agricultural areas. Particular attention was given to Fort Fitzgerald and Bell Rock since they were trans-shipment sites for the river barges before the all-weather road was built from Hay River to Fort Smith in 1967. Collections were also made at Hay Camp (one of the early bison holding areas), and at Sweetgrass (located in the Peace-Athabasca Delta), because of the pressures of continuous heavy bison grazing pressure and the human activity involved in managing the herd since the 1920s. We also suspected weed propagule movement into the Park via the Peace River and Athabasca River because they drain large, upstream agricultural areas.

At each collection site an abundance rating was assigned for each species within 1000 m^2 of suitable habitat. A rating of "rare" indicated one or two individuals of limited reproductive capacity. "Scattered" indicated up to 25 individuals with some reproductive capacity that showed the potential for colonization of new areas. "Frequent" indicated high numbers of individuals, even continuous patches, showing strong reproductive capacity.

Vascular plant collections consulted in the preparation of this paper included the Agriculture Canada collection at Ottawa (DAO) and the University of

TABLE 1. Locations (see Figure 1) and characteristics of collecting sites.

Site	Latitude and longitude	Habitat and general location
1	60°42'N, 114°55'W	Roadside at N.W.T. Hwy 5 at Buffalo River
2	60°43'N, 114°49'W	Roadside at Junction N.W.T. Hwys 5 & 6
3	60°35'N, 114°27'W	Roadside at N.W.T. Hwy 5, km posts 80-88
4	60°26'N, 114°16'W	Sand dune at Angus fire tower, km post 106
5	60°18'N, 114°07'W	Roadside at N.W.T. Hwy 5, km post 123
6	60°08'N, 113°32'W	Roadside at N.W.T. Hwy 5, km post 151
7	60°01'N, 112°21'W	Farms at Salt River, km post 238
8	59°59'N, 112°20'W	Near abandoned St. Bruno Mission Farm
9	60°02'N, 112°05'W	Bell Rock
10	60°00'N, 111°52'W	Townsite — Fort Smith
11	59°55'N, 111°42'W	Roadside at N.W.T. Hwy 5, km post 274
12	59°52'N, 111°35'W	Fort Fitzgerald
13	59°32'N, 111°30'W	Hay Camp
14	59°22'N, 112°25'W	Sand dunes at Cherry Mountain Fire Tower, km post 80
15	59°07'N, 112°26'W	Riverbank — Peace Point
16	58°51'N, 112°00'W	Sweetgrass, heavily grazed by bison
17	58°43'N, 111°10'W	Townsite — Fort Chipewyan
18	58°37'N, 111°38'W	Levees — Prairie River

Alberta Collection at Edmonton (ALTA). Specimens from the present study have been deposited in both herbaria and at the Institut fuer Biologie, Tuebingen University, Germany. Nomenclature generally follows Porsild and Cody (1980).

Results

Species presence

In defining the non-native vascular plants a number of species deserve comments. *Chenopodium album* is often confused with *C. berlandieri* var. *zsachackei,* a native species, especially in immature plants; in western Canada, about 80% of the collections are *C. berlandieri* var. *zsachackei* and about 20% are *C. album.* We have used *C. album* in an inclusive sense. *Juncus bufonius* may be native or introduced. *Medicago falcata* is often considered as a sub-species of *M. sativa* (Small and Brookes 1984), and there is a wide range of hybrids, so we have ignored what we considered to be hybrids. *Achillea millefolium s.l.* may be *A. lanulosa,* but the variation of both is so great that it is difficult to tell them apart except by chromosome number so we have used the former name inclusively.

The 54 non-native species currently recognized as part of the Park flora (Table 2) represent about 10% of the total vascular flora of 594 species (Anonymous 1983). Nine were new records for the area; these were *Sisymbrium altisimum, Sedum spurium, Caragana arborescens, Medicago falcata, Trifolium pratense, Trifolium repens, Vicia cracca, Senecio vulgaris* and *Sonchus arvensis*. The upland landscapes had more non-native species (44) than the Peace-Athabasca Delta (30). Several species were collected earlier but were not located in the present survey. These include: *Agropyron sibiricum, Avena fatua, Spinacia oleracea, Gypsophila paniculata, Ranunculus acris, Camelina sativa, Neslia paniculata*, and *Sinapis arvensis*. *Bromus tectorum* was reported by Upadhyaya et al. 1986, but apparently the collection thought to come from the south shore of Great Slave Lake was actually from Dawson, Yukon Territory. The collection from the Mackenzie River near Norman Wells is correct (R. Turkington, personal communication).

Species abundance

Of the 54 non-native species collected, 12 were estimated to be rare and most of these were found in the upland. Several species are escapes from gardens. *Rheum rhaponticum* is not an invasive weed, but it persists long after gardens have been abandoned. *Veronica longifolia, Sedum spurium* and *Caragana arborescens* are occasional garden escapes but do not appear to be spreading significantly.

Seven species were well established and recorded as frequent; these were *Bromus inermis, Polygonum aviculare, Melilotus alba, Plantago major, Achillea millefolium, Crepis tectorum* and *Taraxacum officinale*. All were found in currently disturbed or previously disturbed vegetation. *Bromus inermis* is the only species that shows some indication of invading sedge communities near roadsides.

Between the rare and frequent species are 35 species that are well established and reproducing successfully; these will likely increase in abundance to some extent and more are likely to be found in new locations in the near future.

Discussion

The mere presence of non-native species is contrary to Canadian Parks Service objectives and there

TABLE 2. Non-native vascular plant species collected at 18 sites in the Wood Buffalo National Park environs. Species nomenclature and order generally follows Porsild and Cody (1980). Field sites are described in Table 1 and the text.

Family and Species	Earlier Collections	1986-1988 Field Sites and Abundance Rating*
Gramineae		
Agropyron pectiniforme R. & S.	Cody (1956) — Fort Smith	10(r), 17(r)
Agropyron repens (L.) Beauv.	Cody (1956) — Fort Smith	5(r), 8(s), 10(s), 12(s), 13(r), 17(s)
Agropyron sibiricum (L.) P.B. Mack	Cody and Porsild (1968) — Fort Smith	**
Avena fatua L.	Raup (1935) — Hay Camp, Cody (1956) — Lower Hay River	**
Avena sativa L.	Raup (1935) — Hay Camp, Porsild and Cody (1980) — Hay River	10(r)
Bromus inermis Leyss.	Cody (1956) — Lower Hay River	8(f), 10(f), 12(f), 13(f), 15-17(f)
Hordeum vulgare L.	Raup (1935) — Hay Camp	7(f)
Phleum pratense L.	Raup (1935), and Cody (1956) — numerous sites	7(s), 8(s), 10(s-f), 16(s-f), 17(s-f)
Poa compressa L.	Raup (1935) — Fort Smith	1 (r)
Juncaceae		
Juncus bufonius L. s. lat.	Raup (1935) L. Mamawi, Pine Lake Raup (1936) — Fort Chipewyan Cody (1956) — Fort Smith, Lower Hay River	8(s-f), 10(s-f), 12(s-f)
Polygonaceae		
Polygonum aviculare L. s. lat.	Raup (1935) — Fort Smith, Moose Lake, L. Mamawi — Upper Slave River	4(f), 7(f), 8(f), 10(f), 12(f) ,14-17(f)
Polygonum convolvulus L.	Raup (1935) — L. Mamawi — Upper Slave River, Pine Lake Cody (1956) — Fort Fitzgerald	10(r), 17(r)
Polygonum lapathifolium L. s. lat.	Raup (1935) — L. Mamawi — Round Lake, Moose Lake	10(r), 16(r), 17(r)
Rheum rhaponticum L.	(garden plant — abandoned farms)	8(r), 10(r)
Chenopodiaceae		
Chenopodium album L.		2(s), 4(f), 7-12(f), 14-18(f)
Spinacia oleracea L.	Cody (1956) — Fort Smith	**
Caryophyllaceae		
Gypsophila paniculata Mack.	Cody (1978) — Fort Smith	**
Stellaria media (L.) Cyrill.	Raup (1936) — Fort Chipewyan	10(r-s), 16(r-s)
Ranunculaceae		
Ranunculus acris L.	Raup (1935) — Fort Smith	**
Cruciferae		
Camelina sativa (L.) Crantz	Raup (1935) — Hay Camp, Pine Lake Cody (1956) — Fort Smith	**
Capsella bursa-pastoris (L.) Medic	Raup (1935) — Hay Camp, Fort Smith	7(r-s), 10(r-s), 14-17(r-s)
Descurainia sophia (L.) Webb	Cody (1956) — Fort Fitzgerald	7(s), 8(s),10(s), 15-17(s)
Neslia paniculata (L.) Desv.	Raup (1935) — Hay Camp Cody (1956) — Fort Smith	**
Sinapis arvensis L.	Raup (1935) — Hay Camp (as *Brassica arvensis*)	**
Sisymbrium altissimum L.	(first report)	17(r)
Thlaspi arvense L.	Raup (1935) — Hay Camp, Cody (1956) — Fort Smith area, Lower Hay River	7(s-f), 8(r-s), 10(f), 12(s), 15(s), 17(f)
Crassulaceae		
Sedum spurium Bieb.	(first report — garden escape)	10(r)
Leguminosae		
Caragana arborescens Lam.	(first report — garden escape)	10(r), 13(r)
Medicago falcata L.	(first report)	10(s), 12(s), 16(s-f)
Medicago lupulina L.	Cody (1956) — Fort Smith	12(r)

Continued

TABLE 2. Continued

Family and Species	Earlier Collections	1986-1988 Field Sites and Abundance Rating*
Medicago sativa L.	Cody (1956) — Fort Smith, Lower Hay River	9(s), 10(s), 12(s), 13(s), 16(s), 17(s)
Melilotus alba Desr.	Cody (1956) — Fort Smith, Lower Hay River	1-3(f), 5(f), 5-17(f)
Melilotus officinalis (L.) Lam.	Cody (1956) — Fort Smith, Lower Hay River	1-3(r-s) , 7-13(r-s), 15-17(r-s)
Trifolium hybridum L.	Cody (1956) — Fort Smith, Hay River	7-9(r), 10(s), 11(r), 12(s), 13-16(r), 17(s)
Trifolium pratense L.	(first report)	2(s), 8(s-f), 10-12(s-f), 16(s-f), 17(s-f)
Trifolium repens L.	(first report)	10-13(s-f), 16(s-f), 17(s-f)
Vicia cracca L.	(first report)	10(r)
Labiatae		
Galeopsis tetrahit L. var. *bifida* (Boenn.) Lej. & Court.	Thieret (1962) — Enterprise	12(r), 17(r)
Scrophulariaceae		
Linaria vulgaris Hill	Cody (1956) — Fort Smith	10(r), 11(f), 17(s)
Veronica longifolia L.	Collected by M. Anions of Fort Smith in 1980	10(r-s)
Plantaginaceae		
Plantago major L.	Raup (1935) — Hay camp, Round Lake, Pine Point, Moose Lake, Fort Smith	1-4(f), 7-17(f)
Compositae		
Achillea millefolium L.	Raup (1935) numerous locations	1-5(f), 7-17(f)
Artemisia biennis Willd.	Raup (1935) Reed Portage, Heart Lake, Moose Lake	8(s), 10(s), 12(s), 16(s)
Chrysanthemum leucanthemum L.	Raup (1935), Pine Lake	9(s), 12(s)
Cirsium arvense (L.) Scop.	(first report)	16(r), 18(s)
Crepis tectorum L.	Cody (1956) — Fort Smith	2(f), 4(f), 7-10(f), 12(f), 14-17(f)
Matricaria perforata Mérat	Cody (1956) — Fort Smith (as *M. inodora* L.)	9(s), 10(s-f), 12(f), 16(s), 17(f)
Matricaria matricarioides (Less.) Porter	Cody (1956) — Ft. Smith	8-17(f)
Senecio vulgaris L.	(first report)	10(r)
Sonchus arvensis L.	(first report) Thieret (1962) Mile 54, Mackenzie Hwy.	2(s), 8(f), 9(s), 10(f), 12(s), 15(s), 16(f), 17(s-f), 18(f)
Tanacetum vulgare L.	Thieret (1962) — North of Fort Smith Cody collected at Fort Smith in 1965	6(r), 18(r)
Taraxacum erythrospermum Andrz.	Cody (1961) — Fort Smith	10(s), 14(s), 15(s)
Taraxacum officinale Weber	Raup (1936) — Ft. Chipewyan	1(f), 4(f), 7-17(f)
Tragopogon major Jacq.	Cody (1956) — Fort Smith	3(r), 5(r)

*r = rare (1-2 individuals/1000m^2), s = scattered (<25 individuals/1000m^2), f = frequent (>25 individuals/1000m^2).
**Not Collected during 1986-1988 survey.

is an awareness that non-native plant species will continue to invade National Parks. Park wardens have recognized few detrimental effects on Wood Buffalo National Park vegetation communities; however, there are several species that are raising concerns. From the point of view of hikers, the increasing numbers of patches of *Cirsium arvense* and the much more widespread *Sonchus arvensis* in the Peace-Athabasca Delta are annoying. Naturalists may be dismayed with roadsides dominated by cultivated legumes and other weedy species.

It is not easy to generalize about the expansion of non-native species over the past few decades because of the few collections and studies in the Park. We have relied on the experience of W. J. Cody who collected in the area in 1950, of local residents, and of Park personnel.

The uplands of the Park have been susceptible to invasion. *Crepis tectorum* was collected in the 1950s by W. J. Cody in Fort Smith but this species along with *Achillea millefolium* and *Taraxacum officinale* have become widespread and abundant. After the

TABLE 3. Non-native vascular plant species (mostly of Eurasian origin) not found in Wood Buffalo National Park but are well established up river in the agricultural regions of Peace River and Fort Vermilion. The list is adapted from Dew (1981) and Thomas et al. (1986), except where noted.

Species Name	Collection Record
Lolium persicum Boiss. & Hohen	
Setaria viridis (L.) Beauv.	Groh (1949)
Polygonum persicaria L.	
Axyris amaranthoides L.	Groh (1949)
Portulaca oleracea L.	Groh (1949)
Amaranthus retroflexus L.	Groh (1949) (collected 1934)
Scleranthus annuus L.	
Silene pratensis (Rafn) Godron & Gren.	
Silene noctiflora L.	Groh (1949)
Spergula arvensis L.	*
Brassica juncea (L.) Coss.	Groh (1949)
Erodium cicutarium (L.) L'Her.	
Euphorbia esula L.	Groh (1949)
Lappula echinata Gilib.	*
Galium spurium L.	
Artemisia absinthium L.	
Centaurea cyanus L.	Groh (1949)
Sonchus asper (L.) Hill	Groh (1949)
Sonchus oleraceus L.	

*Found to be in more than one-third of 220 crop fields surveyed in 1987 (Maurice et al. 1990).

large fires of 1981, these three, wind-dispersed species spread rapidly into the disturbed forests from roadsides but lost their dominance as shrubs and tree seedlings developed a closed canopy (R. W. W., personal observation). Local populations of these three species have been maintained in disturbances such as bison wallows throughout these old burns. Many residents of Fort Smith recognized that aggressive agriculture crop and crop weed species such as *Agropyon repens, Bromus inermis, Phleum pratense, Melilotus* spp. and *Trifolium* spp. have increasingly expanded their range in fine textured soils which have inherently favorable nutrient and moisture regimes. These species have colonized roadsides, settlements and agriculture areas. None of the species have invaded undisturbed vegetation. *Bromus inermis* is the most aggressive in the invasion of the edges of undisturbed shrub and meadow vegetation.

The drier parts of the Peace-Athabasca Delta, and river flood plains of the Park have also been invaded by non-native species. The disturbance regime of water level changes, ice jam scouring and sediment accumulation and removal creates opportunities for the invasion of new species. Coupled with natural changes have been: (1) the changed water regime brought about by the damming of the Peace River in 1968 leading to large areas of the Delta becoming drier, (2) the intensifying of agricultural practices upstream from the Delta on the Peace River and the movement of intensive agriculture toward the Park, and (3) the cutting (until 1992) of timber along the Peace River. Species such as *Chenopodium album* and *Sonchus arvensis* are widespread in the Delta and it is suspected that weed propagules will continue to move downward into the riverside and delta vegetation that is stressed by lower peak water flows.

Predicting potential non-native invaders is speculative but some species are already close to the Park; others may be present but not located as yet. Table 3 lists 20 species now found in the agricultural regions of Peace River and Fort Vermilion that may become established in the Park. Of these, *Setaria viridis, Axyris amaranthoides, Amaranthus retroflexus, Spergula arvensis, Brassica juncea* and *Lappula echinata* have already been collected in the continental Northwest Territories (Porsild and Cody 1980).

Since Park managers and others recognize that low growing non-native species lose dominance as native vegetation (especially shrubs and trees) recovers from disturbance it is important to determine which disturbed areas of the Park will likely be left to recover and which areas will be continually or newly disturbed. Fire will continue to be periodically widespread in the upland forested parts of the Park but the shrubs and tree seedlings create a closed canopy within five years. Roadsides continue to be disturbed periodically by grading and brushing but a greater avenue for invasion would be roads now proposed from High Level to Peace Point and from Fort McMurray to Fort Chipewyan. Farmland near Fort Smith and clearings around all settlements will continue to be prime recipient areas for propagules of

new species. Along the dam-regulated Peace River and in the Peace-Athabasca Delta, vegetation has not yet stabilized within the new hydrological regime so there may be continuing opportunities for agricultural weeds to move downstream and to colonize riverside vegetation. In the past, heavy grazing by bison appears to have enhanced the invasion of species such as *Cirsium arvense* and *Sonchus arvensis* but now that the population of bison has declined precipitously the native vegetation may recover. A more widespread disturbance will be fire which will likely become more frequent as large areas of the Delta continue to develop more upland types of vegetation.

Superimposed on the somewhat predictable disturbances are the potential disturbance brought about by climate change due to the greenhouse effect. Scientists suggest a warming in northwest Canada that would permit southern vegetation zones to be climatically well adapted farther north (Emanuel et al. 1985). Agents of disturbance would eliminate poorly adapted vegetation so expansion of the range of species with weedy characteristics will likely be the first evidence of climate change in northern plant communities. There is some evidence for this hypothesis; experimental studies on the increased warming of soil seedbanks from the Peace-Athabasca Delta show that *Tanacetum vulgare* and to a lesser extent *Cirsium arvense* respond to higher soil temperature (Hogenbirk and Wein 1992).

It is recommended that permanent plots at key locations be established along entrance routes and in disturbed habitats that are likely to be future areas of successful establishment. As invading non-native or native plants are identified, management options can be developed to repel the invasions. For non-native plants that are already established over large areas of the Park, eradication seems impossible. Management strategies that lead to the amelioration of severe disturbances should lessen or stop the advance of non-native vascular plant species. The fact that non-native species have not invaded vigorous native vegetation suggests that a useful management strategy would be to maintain native vegetation that could repel new invaders and possibly lead to the removal of establishing non-native species.

Acknowledgments

This work was part of an interdisciplinary study entitled "Fire in the Taiga" which was coordinated by the University of New Brunswick Fire Science Centre. The project was supported financially by the Natural Sciences and Engineering Research Council of Canada and the Donner Canadian Foundation. We appreciate the continuing interest and support of our research by Wood Buffalo National Park personnel. Contributions on the draft manuscript were provided by P. L. Achuff, who has collected non-native plants in western Canadian National Parks for several years. R. J. Staniforth, University of Winnipeg, C. Crompton and J. Cayouette of Agriculture Canada, Ottawa, A. L. Darwent of Agriculture Canada, Beaverlodge, and two anonymous reviewers also contributed significantly to a draft manuscript.

Literature Cited

Achuff, P. L. 1991. Non-native plant management in Western Region National and Historic Parks: Issue analysis and recommendations, phase II. Report to Canadian Parks Service, Western Regional Office, Calgary, Alberta. 114 pages.

Achuff, P. L., and **I. G. W. Corns.** 1982. Appendix A: Plant checklists. *In* Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume 2: Soil and vegetation resources. *Edited by* W. D. Holland and G. M. Coen. Alberta Institute of Pedology Publication SS–82–44: 515–530.

Achuff, P. L., and **H. A. Dudynsky.** 1984. Appendix A: Plants of Mount Revelstoke and Glacier National Parks. *In* Ecological land classification of Mount Revelstoke and Glacier National Parks, British Columbia. Volume I: Integrated resource description. *Edited by* P. L. Achuff, W. D. Holland, G. M. Coen and K. Van Tighem. Alberta Institute of Pedology Publication M–84–11: 191–212.

Anonymous. 1983. Vegetation. Section 6. *In* Resource description and analysis. Wood Buffalo National Park, Parks Canada, Prairie Region, Unpublished report.

Beckett, E. 1959. Adventive plants at Churchill, Manitoba. Canadian Field-Naturalist 73: 169–173.

Burzynski, M. P., S. J. Woodley, and A. Marceau. 1986. The vascular flora of Fundy National Park, New Brunswick. Publications in Natural Sciences Number 4, New Brunswick Museum, Saint John. 77 pages.

Cody, W. J. 1956. New plant records for northern Alberta and southern Mackenzie District. Canadian Field-Naturalist 70: 101–130.

Cody, W. J. 1961. New plant records from the Upper Mackenzie River Valley, Mackenzie District, Northwest Territories. Canadian Field-Naturalist 75: 55–69.

Cody, W. J. 1978. Range extensions and comments on the vascular flora of the continental Northwest Territories. Canadian Field-Naturalist 92: 144–150.

Cody, W. J., and **A. E. Porsild.** 1968. Additions to the flora of the Continental Northwest Territories, Canada. Canadian Field-Naturalist 82: 263–275.

Dew, D. A. 1981. Survey of weeds in Alberta. Research Station, Agriculture Canada, Lacombe, Alberta. Mimeo. 157 pages.

Emanuel, W. R., H. H. Shugart, and **M. P. Stevenson.** 1985. Climate change and the broad-scale distribution of terrestrial ecosystem complexes. Climatic Change 7: 29–43.

Groh, H. 1937. Peace-Athabasca weeds: A reconnaissance appraisal. Canada Department of Agriculture, Publication 556, Technical Bulletin 7. 42 pages.

Groh, H. 1949. Plants of clearing and trail between Peace River and Fort Vermilion, Alberta. Canadian Field-Naturalist 63: 119–134.

Hogenbirk, J. C., and **R. W. Wein.** 1991. Fire and drought experiments in northern wetlands: a climate change analogue. Canadian Journal of Botany 69: 1991–1997.

Hogenbirk, J. C., and **R. W. Wein.** 1992. Temperature effects on seedling emergence from boreal wetland soils: Implications for climate change. Aquatic Botany 42: 361–373.

Hustich, I. 1971. The introduced flora element in Central Quebec-Labrador Peninsula. Naturaliste Canadien 98: 425–441.

Hustich, I. 1972. On the phytogeography of the Quebec-Labrador Peninsula III. Notes on introduced species. Commentationes Biologicae 54. Societas Scientiarum Fennica, Helsinki-Helsingfors. 28 pages.

Kuchar, P. 1978. The vegetation of Yoho National Park. Report to Parks Canada, Western Regional Office, Calgary, Alberta. 382 pages.

Maurice, D. C., J. T. O'Donovan, and **D. J. Pickle.** 1990. Alberta cereal and oilseeds crop protection survey — Final population results. Alberta Agriculture, Edmonton. Mimeo.

Moss, E. H. 1983. Flora of Alberta. Second Edition, revised by J.G. Packer. University of Toronto Press, Toronto. 687 pages.

Parks Canada. 1983. Parks Canada Policy. Parks Canada, Ottawa. 48 pages.

Porsild, A. E., and **W. J. Cody.** 1968. Checklist of the vascular plants of continental Northwest Territories, Canada. Plant Research Institute, Canada Department of Agriculture, Ottawa. 102 pages plus map.

Porsild, A. E., and **W. J. Cody.** 1980. Vascular plants of the continental Northwest Territories, Canada. National Museum of Canada, Ottawa. 667 pages.

Potyondi, B. 1979. Wood Buffalo National Park: an historical overview and source study. Manuscript Report Number 345. Parks Canada, Ottawa. 255 pages.

Raup, H. M. 1935. Botanical investigations in Wood Buffalo National Park. National Museum of Canada Bulletin 74: 1–174.

Raup, H. M. 1936. Phytogeographic studies in the Athabasca-Great Slave Lake Region, I. Catalogue of the vascular plants. Journal of the Arnold Arboretum 17: 180–315.

Raup, H. M. 1946. Phytogeographic studies in the Athabasca-Great Slave Lake Region. II. Journal of the Arnold Arboretum 27: 1–85.

Roots, E. F. 1989. Climate change: high latitude regions. Climatic Change 15: 223–253.

Small, E., and **B. S. Brookes.** 1984. Taxonomic circumscription and identification in the *Medicago sativa-falcata* (Alfalfa) continuum. Economic Botany 38: 83–96.

Staniforth, R. J., and **P. A. Scott.** 1991. Dynamics of weed populations in a northern subarctic community. Canadian Journal of Botany 69: 814–821.

Stephenson, M. G. 1986. Window on the past: archaeological assessment of the Peace Point Site, Wood Buffalo National Park. Parks Canada, Environment Canada, Ottawa. 145 pages.

Thieret, J. W. 1962. New plant records from District of Mackenzie, Northwest Territories. Canadian Field-Naturalist 76: 206–208.

Thomas, A. G., R. F. Wise, and **G. Clayton.** 1986. Fort Vermilion area of Alberta weed survey in cereal and oil seed fields 1985. Weed Survey Series Publication 86–4, Agriculture Canada, Regina.

Tyser, R. W., and **C. H. Key.** 1988. Spotted knapweed in natural fescue grasslands. Northwest Science 62: 151–155.

Upadhyaya, M. K., R. Turkington, and **D. McIvride.** 1986. The biology of Canadian weeds. 75. *Bromus tectorum* L. Canadian Journal of Plant Science 66: 689–709.

Williams, J. 1987. Plant checklist for Elk Island National Park. *In* M. Dillon Action plan for disturbed sites in Elk Island National Park. Warden Service, Elk Island National Park. 12 pages.

Received 15 April 1991
Accepted 15 September 1992

Food Habits and Observations of the Hunting Behaviour of Arctic Foxes, *Alopex lagopus*, in Svalbard

PÅL PRESTRUD

Norwegian Polar Research Institute, P.O. Box 158, 1330 Oslo Lufthavn, Norway

Prestrud, Pål. 1992. Food habits and observations of the hunting behaviour of Arctic Foxes, *Alopex lagopus*, in Svalbard. Canadian Field-Naturalist 106(2): 225–236.

Food habits of Arctic Foxes in Svalbard were determined by examining 898 stomachs from trapped foxes, by recording prey remains outside dens and by observing feeding and hunting behaviour in the field. Sixty percent of the stomachs contained food. Reindeer (*Rangifer tarandus*) was the most frequently encountered food item (41%) followed by Rock Ptarmigan (*Lagopus mutus*) (30%) and sea birds/fulmar (*Fulmarus glacialis*) (35%). Several other food items were found in the stomachs, supporting the general perception of the Arctic Fox as an opportunistic feeder and scavenger. The weights of different food items in stomachs generally reflected their frequency of occurrence. There were no differences in food habits between sexes, between juveniles and adults, or between seasons. Reindeer, ptarmigan, alcids, fulmars and geese were the most frequently found prey remains at dens. Prey remains from terrestrial species (Reindeer, ptarmigan) were recorded significantly more often at inland dens (>10 km from the coast) than at coastal dens. Remains from Reindeer calves (< 4 months old) were found at several dens, and one adult fox was observed killing a Reindeer calf. Arctic Foxes also preyed heavily on breeding geese. Barnacle Geese (*Branta leucopsis*) did not protect themselves as well as Pink-Foot Geese (*Anser brachyrhynchus*). Arctic Foxes in Svalbard are both skilled predators and scavengers, and they are typical opportunistic and generalistic feeders. Fluctuations in the mortality of Reindeer and in the density of ptarmigan may affect Arctic Fox numbers in Svalbard.

Key Words: Arctic Fox, *Alopex lagopus*, food habits, hunting behaviour, Norway, Svalbard.

The Arctic Fox (*Alopex lagopus*) is distributed throughout the tundra of North America, Eurasia and Greenland. During winter, it ranges widely over the polar pack ice as well. Several studies of its food habits have been conducted in different parts of its range, from which it is apparent the Arctic Fox is an opportunistic predator and scavenger (Shibanoff 1958; Chesemore 1968; Macpherson 1969; Kennedy 1980; Speller 1972; Hersteinsson and Macdonald 1982; Fay and Stephenson 1989; Birks and Penford 1990).

Lemmings (*Lemmus* spp. and *Dicrostonyx* spp.) are the main prey species of Arctic Foxes in the tundra habitat and, because these mammals show cyclic fluctuations in abundance with peaks each 3–5 years, the Arctic Fox populations in this habitat are also subject to cyclic fluctuations (Macpherson 1969). In coastal areas, sea birds, carrion from sea mammals and marine invertebrates are important food items in addition to lemmings (Braestrup 1941; Hersteinsson and Macdonald 1982; Fay and Stephenson 1989). However, where both habitats exist, lemmings are the mainstay of the Arctic Fox's diet especially in years when they are abundant (Braestrup 1941; Garrott et al. 1983; Fay and Stephenson 1989).

There are large populations of Arctic Fox in Iceland, southwestern Greenland, Svalbard and some of the islands in the Bering Sea, even though significant numbers of lemmings and other small mammals are absent. In Iceland and southwestern Greenland, Arctic Foxes feed mainly on Reindeer (*Rangifer tarandus*), Rock Ptarmigan (*Lagopus mutus*), sea birds, waders and waterfowl (Hersteinsson and Macdonald 1982; Birks and Penford 1990). The population dynamics of the Arctic Foxes in the Svalbard archipelago north of the Norwegian mainland are not known. Together with the Glaucous Gull (*Larus hyperboreus*), the Arctic Fox is the only terrestrial predator in the archipelago.

My objective was to determine which prey species could influence possible fluctuations in the size of the fox population and which prey species the Arctic Fox in Svalbard hunted most intensively. In addition, I examined variation in the diet of foxes of different age and sex groups, and compared foxes living inland and along the coast. Observations of hunting behaviour are also reported.

Study Area

Svalbard is the group of islands located between 74°N and 80°N, and between 10°E and 30°E (Figure 1). The area is about 65 000 km^2 and mostly mountainous. Sixty percent of the land is covered by permanent snow and ice and 6–7% is tundra/polar desert vegetation. The climate is relatively warm because of the North Atlantic current and low pressure systems which frequently bring warm air up from the south during winter.

Besides Arctic Foxes, the only other native terrestrial mammal in Svalbard is the Svalbard

Reindeer (*Rangifer t. platyrhynchus*) with a population of approximately 10 000 individuals. Voles (*Microtus* sp.) were introduced to Svalbard accidentally, and have become established locally in some mining towns and in a few bird cliffs along the southern shore of Isfjorden. Their numbers have remained low and they appear to be of no significance to the foxes. Polar Bears (*Ursus maritimus*), Ringed Seals (*Phoca hispida*), and Bearded Seals (*Erignathus barbatus*) are abundant in the adjacent marine waters.

Little Auks (*Alle alle*), Brünnich's Guillemots (*Uria lomvia*) and fulmars (*Fulmarus glacialis*) breed in large numbers throughout the islands. In addition, there are smaller colonies of Kittiwakes (*Rissa tridactyla*), Puffins (*Fratercula arctica*) and Black Guillemots (*Cepphus grylle*) scattered around the archipelago. Eiders (*Sommateria mollisima*) are common along the western coast together with Pink-Footed Geese (*Anser brachyrhynchus*) and Barnacle Geese (*Branta leucopsis*). Other duck and goose species are found in low numbers. The Snow Bunting (*Plectrophenax nivalis*) is the only breeding passerine. The Purple Sandpiper (*Calidris maritima*) is the only abundant breeding wader. Rock Ptarmigan are also sometimes abundant, but seems to fluctuate in density between years. They are the only bird species that regularly winters in the islands.

Materials and Methods

The food habits of Arctic Foxes were studied by analyzing the contents of stomachs removed from carcasses purchased from professional and recreational hunters during the hunting season (1 November-15 March, extended to 1 May in 1987) in 1977-1980, 1981-1984 and 1985-1989, and from specimens shot from May through September 1985-1987. Trapped foxes were caught in baited Spitsbergen traps (75 × 75 cm wooden frame covered with 30–40 kg stone which falls down and kills the fox when the bait is touched). In most cases, the trappers provided information about the date, area of capture and bait used.

Carcasses were stored frozen for up to eight months before the stomach contents were analyzed. The stomach contents were weighed to the nearest 5 g, and washed to separate the contents into heavy (food items which sank) and light fractions (those which remained on the water surface). Each fraction was then filtered in a sieve (approximately mesh size 1 mm) before being partially dried. Food items were separated into nine categories: Reindeer, seal, Ptarmigan, Fulmar, sea birds (alcids and gulls), marine items (invertebrates, fish, sea weed), garbage, vegetation/soil (vegetation, soil, sand, stone) and other/unidentified. When possible, food items were identified to genus or species, based primarily on the colour and texture of plumage, pelage, bill, claws and bones. The volume of each food category was estimated by eye to the nearest 10% of the total volume of the stomach content. Weight of a food category was calculated by multiplying the weight of the stomach content with the volume percent of that particular food category.

Stomaches with contents that weighed less than 2.5 g were considered empty. Materials such as single or a few feathers, single or small amounts of hair and single pieces of bone were considered to have no nutritive value and were not recorded. Thus, our method accounts only for significant items of food found in the stomachs.

The ages of most foxes sampled were determined by counting the incremental lines in the cementum of a sectioned lower canine tooth (Grue and Jensen 1976). Foxes born in May/June were called juveniles until July 1 of following year. All other foxes were called adults. The sex of each animal was recorded.

The remains of prey found at dens in an 975 km^2 study area southeast of the inner part of Isfjorden (Figure 1) were recorded in August-September from 1983 through 1989. Dens were located in 1982-1988 by systematic searching through the area, and remains of food items found there were recorded once each year. Thirty-one breeding dens (where pups were recorded once in the period) and 10 assumed breeding dens (large den with substantial prey remains, but no sign of pups) and 15 shelters (small dens, few or no prey remains, no sign of pups), were mapped. Dens <10 km from the coast were defined as coastal dens.

Prey remains at each den were counted, and the following categories were identified: Reindeer (after the summer 1985 I distinguished between adults and calves), seal, ptarmigan, fulmar, alcids (Little Auk, Brünnich's Guillemot, Puffin, Common Guillemot (*Uria aalge*), Black Guillemot), gull (Kittiwake and Glaucous Gull), water fowl (anatids and anserids), garbage and other/unidentified. All loose feathers or hairs from one species were considered to represent the remains of one prey item. Similarly, a single bone, wing, head, leg, foot or whole carcass were also considered one item each and counted once. For example, a bird carcass with the wings separated from the carcass was counted three times. Remains were classified as either fresh (from last summer/spring) or old (from previous summers/years) remains. Old (≤ 1 yr) remains were recorded only once during the study. Reindeer antlers were not counted as they were considered non-food items.

Feeding and hunting behaviour of Arctic Foxes were observed in the field on an opportunistic basis from 1982 through 1989. When dens were observed to estimate litter size, food items were identified and recorded if possible when adults brought food to their pups.

Statistics

Statistical methods follow Zar (1984). Frequency of occurrence of different food categories in the

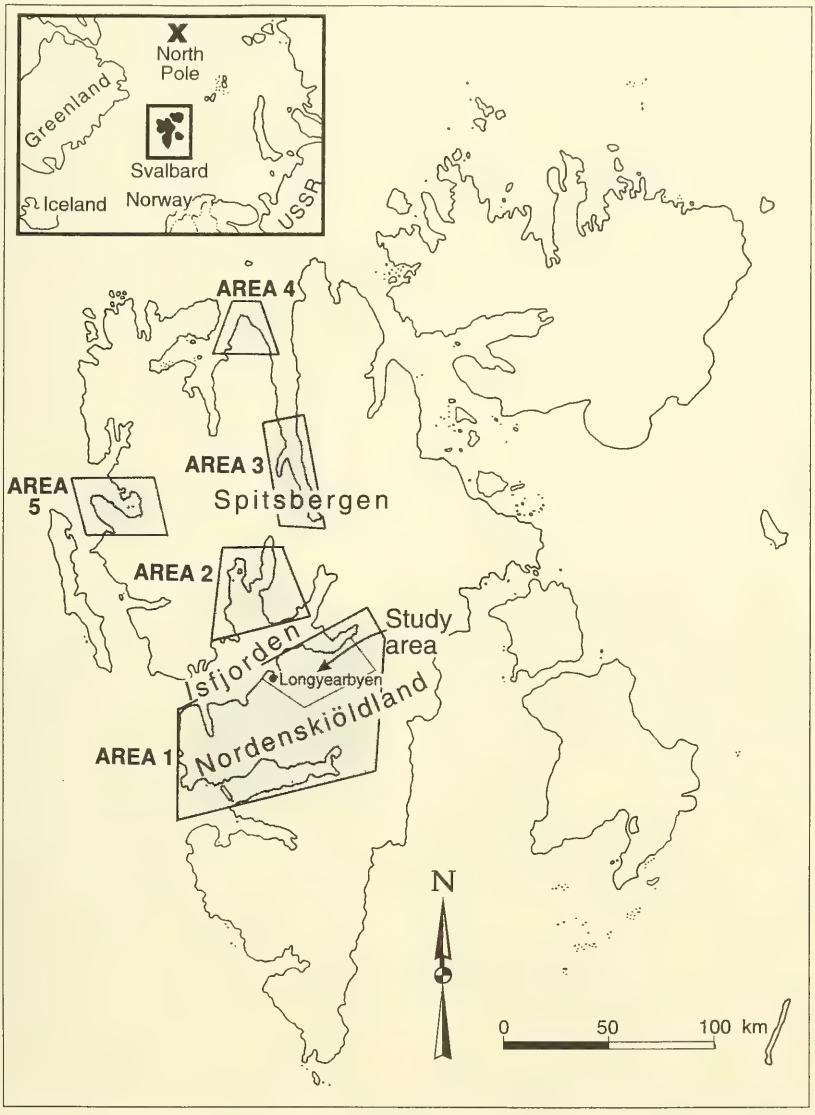


FIGURE 1. Map of Svalbard showing areas where carcasses of Arctic Foxes were collected. Area 1 = Nordenskiöldland, Area 2 = Kapp Wijk, Area 3 = Ausfjorden, Area 4 = Gråhuken, Area 5 = Ny Ålesund.

stomach contents and at dens was compared using χ^2 tests and contingency tables. Yates correction was used when df = 1. Variation in weight of the stomach contents was tested by t-test or one-way ANOVA. Simple linear correlation analyses (r) were used to examine the relationship between the average number of remains in one food category found in dens and the distance between the sea and the den locality. For all tests, probabilities less than 0.05 were considered significant. Data were analyzed using Statgraphics (STSC Inc. 1987, version 2.61) statistical software.

Results

Analysis of stomach contents

Stomachs were collected from foxes trapped in different areas (Area 1, 638 foxes; Area 2, 103 foxes; Area 3, 100 foxes; Area 4, 38 foxes; Area 5,

TABLE 1. Number of stomachs with and without contents, mean weight of stomach contents (± SD), and frequency of occurrence (%) of food items in Arctic Fox stomachs of different sexes, age groups and in foxes caught in winter (October–March) and summer (April–September).

	Sex		Age		Season	
	♀	♂	Juv.	Ad.	Winter	Summer
No. empty stomachs	184	178	194	163	339	24
No. stomachs w/food	239	297	308	222	512	22
Weight of stomach cont.(g)	56 ± 41	57 ± 38	54 ± 36	59 ± 41	57 ± 39	47 ± 38
	% frequency of occurrence in stomachs					
Reindeer	40	42	43	39	42	23
Seal	3	6	5	4	5	5
Ptarmigan	31	28	30	29	30	14
Fulmar	15	22	16	21	17	45
Sea birds	16	18	18	16	16	41
Marine items	6	10	8	7	8	5
Garbage	5	5	5	5	5	9
Vegetation/soil	5	6	5	5	6	5
Other/unidentified	15	12	10	18	13	9

19 foxes; *see* Figure 1). Of the stomachs examined (n = 898), 60% contained food. Reindeer was the most frequently encountered food item (41% of the stomachs containing food), followed by ptarmigan (30%) (Table 1). Sea birds or fulmars were found in 35% of the stomachs. *Uria spp.* (assumed to be mainly Brünnich's Guillemot) and Little Auk dominated in the category "sea birds", but also Puffin (2 stomachs), Kittiwake (10 stomachs) and Glaucous Gull (1 stomach) were identified. Remains of seals were found in 23 stomachs. No remains of white coat pups were recorded.

Marine invertebrates were found in 8% of the stomachs, and comprised sea urchins, tunicates, gastropod eggs, gastropod shells and small decapods (mostly small crabs) (Table 1). Seaweed was found in 28 stomachs and fish in one. Plastic and paper garbage were encountered frequently, and cooked shrimp, ham, sausage, bacon, bread, cloth, raisins and apple seeds were also found. Small stones and sand, in addition to grass and mosses dominated in the category "vegetation/soil". In the category "other/unidentified", meat, fat, bone fragments, feathers and hair dominated. Snow Bunting (4 stomachs), Eider (5 stomachs), small mammal (assumed to be *Microtus* sp., 2 stomachs) and Old Squaw Duck (*Clangula hyemalis*, 1 stomach) were identified. No remains of geese or waders were found.

There were no significant differences between sexes in the frequency of occurrence of food items ($\chi^2 = 9.5$, $p = 0.30$, $df = 8$), in the number of stomachs with and without contents ($\chi^2 = 3.1$, $p = 0.08$, $df = 1$) or in the average weight of the stomach contents ($t = 0.08$, $p = 0.93$) (Table 1). Similarly, there were no significant differences between juvenile and adult foxes in the composition of food items in their stomachs ($\chi^2 = 8.4$, $p = 0.39$, $df = 8$), in the proportion with and without contents ($\chi^2 = 1.09$, $p = 0.30$, $df = 1$) or in the average weight of their stomach contents ($t = 1.4$, $p = 0.16$) (Table 1).

Fulmars and other sea birds occurred most frequently during summer, while Reindeer predominated during winter (Table 1). The small sample size of stomachs collected in summer precluded statistical testing for differences between seasons in the composition of food items and the proportion of stomachs with and without contents. There was no significant difference in the weight of the stomach contents between winter and summer ($t = 1.2$, $p = 0.24$).

The mean weights of remains of Reindeer, seal, ptarmigan and fulmar in fox stomachs were significantly larger than those of marine items, garbage, vegetation and other/unidentified (one-way ANOVA: $F = 9.6$, $p < 0.001$, $df = 9$, Tukey test)

TABLE 2. Mean weight (± SD) and mean volume (± SD) of different food categories in Arctic Fox stomachs.

	n	Weight (g)	Volume (%)
Reindeer	220	52 ± 3.2	83 ± 2.0
Seal	23	51 ± 7.2	79 ± 6.4
Ptarmigan	159	42 ± 2.6	75 ± 2.7
Fulmar	100	44 ± 3.6	70 ± 3.3
Sea birds	92	31 ± 3.4	56 ± 5.4
Marine items	43	19 ± 2.7	53 ± 6.3
Garbage	27	24 ± 6.2	40 ± 7.9
Vegetation/soil	30	11 ± 3.2	26 ± 5.7
Other/unident.	76	23 ± 3.0	52 ± 4.8

TABLE 3. Number of empty and not empty stomachs, mean weight of stomach content (± SD) and frequency of occurrence (%) of food items in Arctic Fox stomachs containing food and collected from different trapping areas in Svalbard (area number refers to map, Figure 1).

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5
No. empty stomachs	240	52	51	10	9
No. stomachs w/food	398	51	49	28	10
Weight of stomach contents (g)	56 ± 38	57 ± 32	49 ± 35	57 ± 33	60 ± 41
	% frequency of occurrence in stomachs				
Reindeer	49	4	14	48	10
Seal	2	4	22	4	20
Ptarmigan	31	25	45	4	10
Fulmar	17	47	6	4	40
Sea birds	16	16	23	15	80
Marine items	8	18	4	0	0
Garbage	6	2	4	0	10
Vegetation/soil	6	6	2	11	0
Other/unidentified	14	12	12	33	10

(Table 2). The mean weight of sea bird remains was not significantly different from any of the other food categories. Significantly fewer of the stomachs from foxes caught in Nordenskiöldland (area 1) were empty (38%) than stomachs collected north of Isfjorden (47%) (area 2-5) ($\chi^2 = 6.3$, $p < 0.05$, df = 1) (Table 3). The composition of the stomach contents from Nordenskiöldland and from areas north of Isfjorden were also significantly different ($\chi^2 = 56.5$, $p < 0.01$, df = 4). This was due to differences in the frequency of occurrence of Reindeer in stomachs from foxes caught in the two areas (Table 3). The average weights of stomach contents from foxes caught in different areas in Svalbard were not significantly different (one-way ANOVA: $F = 0.5$, $p = 0.89$, df = 3).

There were no significant changes in composition of diet ($\chi^2 = 8.8$, $p = 0.36$, df = 8), frequency of empty/not empty stomachs ($\chi^2 = 2.7$, $p = 0.60$, df = 4) or in the mean weight of the stomach contents (one-way ANOVA: $F = 2.1$, $p = 0.08$, df = 4) from November through March (Table 4).

About 90% of the traps were baited with ptarmigan. Since traps often do not release if they became clogged by drifting snow, it is possible that trap baits could be a source of food and bias the data. This was tested by comparing the contents of 61 stomachs collected from areas where traps were baited only with blubber and sea birds, with stomachs from areas where traps were baited with ptarmigan. Eighteen percent of the stomachs from areas where other baits were used had remains of

TABLE 4. Number of empty and not empty stomachs, mean weight of stomach contents (± SD), and frequency of occurrence (%) of food items in Arctic Fox stomachs containing food and collected during winter.

	November	December	January	February	March
No. empty stomachs	55	67	87	59	35
No. stomachs w/food	97	116	130	79	44
Weight of stomach contents (g)	57 ± 27	57 ± 33	56 ± 34	55 ± 40	75 ± 59
	% frequency of occurrence in stomachs				
Reindeer	32	39	47	39	52
Seal	10	2	5	3	0
Ptarmigan	32	30	25	30	27
Fulmar	19	23	12	18	21
Sea birds	22	15	19	13	5
Marine items	7	17	8	4	0
Garbage	5	5	7	3	2
Vegetation/soil	7	4	6	8	0
Other/unidentified	17	9	17	14	11

TABLE 5. Frequency of occurrence (%) and mean number of prey remains (± SD) found at dens in August/September after pups had left the den.

	% frequency of dens		
	Fresh (n=77)	Old (n=45)	Mean number of fresh prey remains
Reindeer	82	98	12 ± 11.3
Seal	9	4	2 ± 0.3
Ptarmigan	55	36	2 ± 2.7
Fulmar	53	36	6 ± 6.3
Alcids	62	27	16 ± 24.2
Gull	12	4	3 ± 1.9
Waterfowl	43	27	3 ± 2.6
Garbage	4	9	1 ± 0
Other/unident.	22	7	2 ± 0.6

Fresh = prey remains from recent summer/spring
Old = prey remains from previous summers

ptarmigan, while 30% of the stomachs from areas where traps were baited with ptarmigan had ptarmigan remains, a difference that was not significant ($\chi^2 = 1.7$, $p = 0.19$, $df = 1$).

Prey remains at dens

Reindeer showed the highest frequency of occurrence, but ptarmigan, fulmar, alcids and waterfowl were also commonly found at dens (Table 5). The remains of Reindeer were mainly limbs, lower jaws, scapulas and, less frequently, skulls, vertebrae and parts of the pelvic girdle. Eighty-one fresh items of calves (born in June and died the same summer) were found at 21 dens. In August 1988, a 30 cm long non-furred Reindeer foetus with the head and back intact, was found in a den entrance. It may have been cached inside the den and was not present when that den had been visited one month earlier.

Remains from birds consisted mainly of feathers, wings and whole carcasses. *Uria* spp. (mainly Brünnich's Guillemot) (32 dens), Little Auk (17 dens) and Puffin (18 dens) dominated among the alcids, but remains of Black Guillemot were also found at 2 dens. In 1987, large numbers of carcasses of *Uria* spp. in winter and summer plumage were detected at dens in the inner part of Isfjorden. At one den, 56 whole carcasses were found and both the Brünnich's and the Common Guillemot (at least six) were identified. Kittiwakes and Glaucous Gulls were found at 6 and 2 dens respectively. Egg shells from sea birds were recorded at two dens, and sea bird chicks at three dens.

Remains of waterfowl were frequently found at the dens in the eastern part of the study area (Table 5). Fresh remains of Pink-Footed Geese (18 dens), Barnacle Geese (11 dens), and Eiders (9 dens) were encountered most often. Egg shells from waterfowl were found at 6 dens, and goslings were found at 4 dens. The rest of the remains were from adult or juvenile birds. Remains of King Eiders (*Somateria spectabilis*) (2 dens) were also recorded.

TABLE 6. Frequency of occurence (%) of fresh prey remains at inland dens (>10 km from the coast) and coastal dens (<10 km from the coast).

	Coastal den (n=54)	Inland den (n=23)
Reindeer	76	96
Ptarmigan	48	70
Fulmar	61	35
Alcids	78	26
Waterfowl	39	39

All seal remains were from Ringed Seals. The remains of the white coat pups were found at three dens.

In the category "other/unidentified", Snow Buntings (12 dens) were most common. Remains of a Purple Sandpiper, Skua (*Stercorarius skua*), Grey Thrush (*Turdus pilaris*) and an unidentified fish were found at only one den each.

Remains of alcids were most numerous, but the numbers differed greatly between different dens (large variance). At one den situated in a colony of Little Auks, 99 fresh whole carcasses and wings of this species were found. Remains from Reindeer were also numerous, and were probably a more important dietary item than alcids because the latter often left numerous wings and tarsuses which increased the number of recordings without representing significant amounts of energy.

Remains from Reindeer and Ptarmigan were found more frequently at inland dens than at those along the coast (Table 6). In contrast, alcids and fulmars occurred more frequently at dens along the coast. The difference between coastal and inland dens in the frequency of occurrence of prey remains was significant ($\chi^2 = 11.0$, $p < 0.05$, $df = 3$). This difference was also reflected in the average number of remains of each prey type found at different dens: the number of remains of Reindeer and ptarmigan increased significantly with the distance from the sea (Reindeer: $r = 0.50$, $p < 0.001$; ptarmigan: $r = 0.31$, $p < 0.01$), while the mean number of prey remains from alcids and fulmars decreased significantly (alcids: $r = -0.39$, $p < 0.001$; fulmars: $r = -0.43$, $p < 0.001$), as distance from the sea increased.

Observation of feeding and hunting behaviour

I observed adult foxes carrying identifiable prey (including eggs) in their mouths on 62 occasions during summer. These prey were comprised of 31 alcids or Fulmars, 15 geese, one adult female Eider, 11 pieces of Reindeer, two Purple Sandpipers and two Snow Bunting chicks. Adult foxes sometimes delivered food to the pups by regurgitating, in which case it was not possible to identify prey.

Sea birds

The talus under steep bird cliffs was regularly patrolled by foxes for remains of fallen sea bird chicks and eggs. Twelve foxes were observed finding food in this way. Foxes were also able to climb onto some ledges where sea birds were breeding. On three occasions foxes were observed taking chicks and eggs on ledges. P. E. Fjeld (personal communication), observed a female fox that took four eggs and three chicks of Brünnich's Guillemot from nests on a ledge. It took one item at a time and buried it at the same place in the vegetation 2–3 meters from the ledge. When the ledge was empty, she took each item, one at a time, to a den 2.5 km away. A Glaucous Gull observed the fox, and stole 1 or 2 chicks from the cache while the female was at the den.

One fulmar and three Little Auks were observed being killed by Arctic Foxes after being forced to the ground by Glaucous Gulls. In all four cases, the foxes were attracted by noises from the birds. I also observed Arctic Foxes scavenging along beaches where dead or sick birds drifted ashore.

Geese

I observed 11 attacks by adult foxes on Pink-Footed Geese at nest sites or moulting areas. When flocks were attacked, adult geese gathered around goslings, spread their wings, raised their necks and faced the attacking fox. I also saw single pairs of geese at nest sites (three observations), or taking newly hatched goslings to the nearest water (two observations), use the same tactic. The fox usually initiated its attack from a distance of more than 10 meters (in one case as far away as about 1100 meters) and ran at high speed straight into the geese. The geese met the fox with their breasts, often jumping at it, while simultaneously beating with their wings and biting. The foxes were pursued for a few meters by the geese. On seven occasions attacks were repeated, and in one case a fox sustained its attack for 12 minutes with at least seven assaults. Three to five non-breeding geese sometimes also helped parents defend nests. In one case, a fox managed to dislodge a goose from its nest long enough to take one egg. The fox remained under sustained attack by several geese until it was 50–100 meters from the nesting colony.

In one case, a fox was observed just after it had killed an adult Pink-Footed Goose. The neck and head were bitten off, some of the goose was eaten and the rest buried. On three occasions adult foxes were observed bringing goose eggs to dens. The eggs were probably from Pink-Footed Geese, as the nests of Barnacle Geese were mainly located in steep cliffs inaccessible to foxes.

I observed three cases (all in July), in which feeding flocks of Barnacle Geese were attacked when they tried to escape to the nearest pond. During the attack, goslings pressed themselves to the ground and lay quietly. The adults spread out on the tundra and were not attacked. If the fox did not find a gosling in short time, it ran 2–300 meters away, lay down in the vegetation, and watched the geese. It attacked again when the geese started to move towards the pond and it could see the goslings. In the three episodes I observed, at least eight goslings were taken. They appeared to have been killed by having their necks broken after being bitten or shaken. Two of these goslings were brought to a den and hidden inside, and the rest were buried without being eaten. In one case, I observed two adult foxes attacking the same flock of Barnacle Geese. The foxes were in close contact several times, but showed no aggressive behaviour to each other. Neither seemed dominant. However, there was no indication their hunting was coordinated.

On one occasion a Glaucous Gull was observed as it killed a Barnacle gosling on a pond by pushing it under water and biting it in the head and neck. After the gosling was dead, the gull swam with it towards the beach. An adult fox, hiding in vegetation, watched the gull. When the gull was 10–15 m from the shore the fox jumped into the water, swam out and took the gosling, carried it to a den (1500 m from the pond), and left it inside (the pups had left the den 1-2 weeks earlier) before laying down outside the den. After 10 minutes, a Glaucous Gull attacked the Barnacle Geese again. The noise attracted the fox's attention and it immediately ran back to the shore of the pond and hid in the vegetation. However, this time the gull was unsuccessful.

Reindeer

Foxes fed extensively on Reindeer carcasses, and all carcasses found during the summer had been scavenged by foxes. In most cases the abdomen of the Reindeer was opened first. In three cases the carcasses were completely covered by 30–50 cm of snow and the foxes had dug 2–3 tunnels down to them. In one instance, there was so much fox and Reindeer hair inside the carcass that it appeared to have been used temporarily as a den, providing both food and shelter.

Arctic Foxes were observed attacking Reindeer on six occasions between June and August, and in one of these the fox succeeded. In all cases our attention was drawn to the attacks by abnormal behaviour of the Reindeer. In four cases the fox attacked females with calves, and in two cases it attacked small herds of mixed sex and age. The fox always attacked by running into the Reindeer at high speed. In most cases these appeared to be mock attacks, since active biting did not seem to occur. The Reindeer mainly reacted by fleeing, but some also tried to chase the fox away. In all but one of the observed cases the fox attacked several times (2–7).

From a distance of about 500 meters, one of my assistants observed in detail how a calf (about one month old) was killed by an adult fox. The attack began before the observation began. The fox attacked at high speed, jumping at the calf and biting it repeatedly on the flanks and limbs. The female Reindeer tried to protect the calf by chasing the fox 50–100 m away several times. The fox would then attack again, while the much slower female Reindeer trailed several meters behind. This pattern of behaviour continued at a high intensity for about 20 minutes. The fox lay down for 8 minutes after being chased 200–300 m away from the calf, but then resumed its attack. After a few minutes the female Reindeer was exhausted, began to stumble, and could no longer protect the calf. By this time the calf was running around its mother while being attacked repeatedly by the fox. Forty-one minutes after the observation began, the calf fell and was killed by several bites in the chest and neck region. The female Reindeer stood on her metacarpus at a distance of 5–10 m without attempting to protect the calf. She left after 17–18 minutes and 23 minutes later, the fox also disappeared.

Two adult foxes were seen feeding on the carcass three hours later. One of them was similar in size and colour to the fox that killed the calf. The other was a radio-collared adult female that had six pups in a den 3 km away. The calf was killed inside her home range, and she was at the den when the calf was killed. Both foxes buried parts of the calf within 700–800 m of the carcass. After 1–1½ hours only some of the pelage remained and both foxes left.

Other observations

On seven occasions I saw foxes apparently searching for food by placing their nose close to the ground, and rapidly trotting in a zigzag pattern over the tundra. In one case an adult fox found two Purple Sandpiper nests, ate all the eggs, and then went directly to its den (ca. 800 m away) where it regurgitated to the pups. In another instance, where one or two Purple Sandpiper chicks were taken, the fox watched from a distance of about 50-100 m until the chicks moved from their hiding places. It then ran towards the chicks and the adult bird. It ignored the distraction display of the adult bird.

Discussion

Methods

Analysis of stomach contents are probably more accurate than scat analysis because material is not lost to digestion. This method has often been used to study food habits of carnivores, including Arctic Foxes (Macpherson 1969; Fay and Stephenson 1989). It should be stressed that the method used in this study to analyze food items in stomachs emphasizes recording the predominant food types. Prey species which only occurred in trace amounts were less well quantified.

The specific weights of different food items recorded in stomachs are obviously not similar, for example feathers weigh less than meat or fat. The weights of different food categories in stomachs (Table 2) are therefore overestimated for food items of low specific weights (i.e., feathers, garbage, gastropod eggs and shells), and underestimated for food items of light specific weights (i.e., meat, bones) when these different food items are found in the same stomach. Consequently, the figures given in Table 2 can only be regarded as approximations of the relative proportions by weight of the different food categories.

Garrott et al. (1984) never observed adult Arctic Foxes regurgitating stomach contents to pups. In Svalbard adults did, and the content was difficult to identify, even if an observer was nearby. Recording prey remains outside dens will therefore only give a qualitative assessment of the importance of different types of food in the diet of foxes during summer. Moreover, larger items and hard parts, such as bones, tend to be over-represented in the uneaten remains near the dens (e.g., Floyd et al. 1978).

Food habits

The diversity of food items eaten by Arctic Foxes in Svalbard, identified in stomachs, found outside dens, and observed during field observations support the general conclusion that Arctic Foxes are opportunistic and generalistic feeders (e.g., Shibanoff 1958; Chesemore 1968; Macpherson 1969; Speller 1972; Garrott et al. 1983; Hersteinsson and Macdonald 1982; Fay and Stephenson 1989; Birks and Penford 1990). They prey on most available animals, and scavenge carrion and garbage whenever possible.

Reindeer was found most frequently in stomachs, and constituted the greatest volume of all food items. It was also the most frequently occurring prey remain found outside dens. Remains from Reindeer at dens were most often large items, easy to count, and possibly over-represented in comparison to birds. However, meat and fat of Reindeer with no or few indigestible parts were brought to dens on some occasions, leaving no remains. Thus, while more individual pieces of birds were recorded (Table 5), the bird remains most likely represented less biomass than did Reindeer. Even after considering possible biases in the data, it is clear that Reindeer was the most important food for Arctic Foxes in both summer and winter.

The importance of Reindeer is not surprising because on an annual basis they probably represent the largest biomass of potential fox food. In some years the mortality of Svalbard Reindeer is as high as 25 percent (Tyler 1987). Despite scavenging by

both Glaucous Gulls and Arctic Foxes some intact carcasses remained until the following winter. Remains of Reindeer or Caribou have frequently been found in fox scats, digestive tracts and at dens in arctic Canada and Alaska (Chesemore 1968; Macpherson 1969; Speller 1972; Kennedy 1980) although lemmings and birds are generally thought to be more important food sources in these areas. However, in southwestern Greenland, where small mammals are absent as they are in most of Svalbard, Reindeer is also the principal food of Arctic Foxes (Birks and Penford 1990).

My observation of an Arctic Fox killing a calf and the frequent occurrence of calf remains at dens suggest that Arctic Foxes in Svalbard are successful predators on Reindeer calves. People engaged in reindeer husbandry in northern Scandinavia have claimed that Arctic Foxes prey on Reindeer calves, but no documentation exists. Macpherson (1969) found that the remains of Caribou in Arctic Fox scats (15% of the scats he examined) from arctic Canada were largely from calves.

Medium-sized birds were the second most important food source in both winter and summer. Ptarmigan are common in Svalbard and occur on most of the islands. Although ptarmigan were often used to bait fox traps, this did not significantly bias the analysis of fox stomach contents.

Alcids and gulls, and most of the fulmars, are absent from Svalbard in winter, and the occurrence of these species in stomachs from foxes caught in winter (Table 1) most likely results from extensive caching during summer. Observations of Arctic Foxes caching food are numerous. Fay and Stephenson (1989) and Prestrud (1991) concluded that this behaviour is important to the survival of Arctic Fox populations throughout their range. My results support this conclusion.

The Common Guillemot breeds in large numbers in the southern Barents Sea. There are only a couple of hundred breeding pairs in Svalbard (except for Bear Island and Hopen where several thousand pairs nest). In 1986/87 the Capelin (*Mallotus villosus*) population in the Barents Sea crashed due to overexploitation and 80–90% of the Common Guillemots in some colonies died because of food shortage (Bakken and Mehlum 1988). The following summer (1987) was the only time carcasses of Common Guillemots were found at fox dens and along beaches in the inner part of Isfjorden during this study.

Where geese were present they constituted an important summer food source for Arctic Foxes (Table 5). Geese bred in about half the area where dens were recorded and their remains were found at all adjacent fox dens. Prey remains at dens suggest that Arctic Foxes sometimes kill adult geese, although we did not observe this. The importance of geese to foxes has ranged from minor (Birks and Penford 1990) to major (Speller 1972) in other areas studied.

Few remains of Eiders were found in either stomachs or at dens and they do not seem to be a significant food source. Although the Svalbard Eider population probably exceeds 100 000 individuals, most breed on small islands which are usually inaccessible to Arctic Foxes (Prestrud and Mehlum 1991). In some years foxes are present on these islands. This appears to preclude Eider nesting (Prestrud, unpubl.) as it does in Alaska (Quinlan and Lehnhausen 1982). Eiders may be an important food source under special conditions, but are generally of little importance to Arctic Foxes.

Larson (1960) suggested that predation by Arctic Foxes significantly influences the distribution of arctic birds. Summers and Underhill (1987) found a correlation between breeding success of Brent Geese (*Branta bernicla*) and waders on the Taimyr peninsula in Siberia, and the abundance of lemmings. They suggested that Arctic Foxes prey heavily upon birds when lemmings are scarce, but ignore them when lemmings are abundant. In Svalbard, fluctuations in the availability of Reindeer carcasses or Ptarmigan may have a similar influence on fox predation on migratory birds.

Arctic Foxes often scavenge the remains of seals killed by Polar Bears (Stirling and Smith 1977) and in some years prey Ringed Seal pups in subnivean birth lairs (Smith 1976). Polar Bears come to the west coast of Svalbard in March to hunt seals in the fiords. The majority of the fox stomachs examined in the western part of the archipelago were collected before mid-March. This probably accounts for the scarcity of seal remains. It is likely that seals are more important in the late winter diet of Arctic Foxes than my data indicate, as suggested by studies of predation on Ringed Seal pups in Svalbard (Lydersen and Gjertz 1986).

Marine invertebrates and seaweed often occur in stomachs and scats of Arctic Foxes living in coastal areas (Fay and Stephenson 1989). However, the generally low frequency of occurrence of marine food items (Table 1) and their low weight in stomachs (Table 2) implies they are of minor importance to Arctic Foxes in Svalbard.

Eberhardt et al. (1982) and Garrott et al. (1983) suggest that in northern Alaska garbage dumps in developed areas may provide enough food to maintain higher Arctic Fox populations than would otherwise be found. Although garbage dumps were present, I found little garbage either in stomachs or outside dens (Table 1, Table 5).

The variation in diet between different areas (Table 3) can be at least partly explained by the distribution of Reindeer in Svalbard. Nordenskiöldland (Area 1) has the highest density of Reindeer. Reindeer are absent from the north side of Isfjorden,

and their remains were scarce in fox stomachs from that area (Area 2–5 in Table 3, Figure 1). Gråhuken (Area 4) has a high Reindeer population and Reindeer occurred frequently in fox stomachs from this area. Food occurred in significantly more stomachs from Nordenskiöldland than from areas north of Isfjorden, suggesting that the lack of Reindeer makes this latter area a less suitable habitat for Arctic Foxes. Ptarmigan and sea birds appeared to replace Reindeer as the most important foods where Reindeer were absent.

Prestrud and Nilssen (1992) showed that body weight and fat deposits of Arctic Foxes do not change from November to March, suggesting that they are not in negative energy balance during winter. Neither the diet nor the number of empty stomachs changed through the winter (Table 4), also suggesting that Arctic Foxes in Svalbard do not normally experience a winter food shortage.

Foxes having dens near the coast fed more intensively on marine prey species (alcids and fulmars) than did foxes denning elsewhere which mainly fed on terrestrial prey (Reindeer and ptarmigan). However, the correlation between number of ptarmigan and Reindeer and the distance from the sea was weak, indicating that the distinction between "inland foxes" and "coastal foxes" in Svalbard is not well defined. Reindeer and ptarmigan are distributed along the coast as well as inland, and sea birds such as fulmars and Little Auks nest in both areas. Moreover, few areas in Svalbard are more than 20-30 km from the coast. Consequently, ecological differences between Arctic Foxes living at the coast and inland in Svalbard are probably minor.

Hunting behaviour

There are few published descriptions of the hunting behaviour of Arctic Foxes. Caley (1972) reported that captive Arctic Foxes caught mice with a swift rush following visual identification. I observed similar behaviour when foxes attacked geese and Reindeer, which is typical for this species (Fox 1969). Red Foxes (*Vulpes vulpes*) in forest habitat hunt mainly by stalking followed by a lunge (Henry 1980). Caley (1972) suggested the technique of quickly rushing at prey is better suited to the tundra where little cover exists. Speller (1972) studied the behaviour of Arctic Foxes hunting lemmings and described how Arctic Foxes stalked prior to dashing and pouncing or digging out burrows. However, the tundra habitat in his study area supported relatively high vegetation where a fox could hide. I never observed such behaviour in the more open, less vegetated tundra in Svalbard, indicating the hunting strategy of Arctic Foxes depends on habitat.

The short legs and overall body structure of the Svalbard Reindeer are not adapted for running and less than 1% of their activity budget is used on this behaviour (Tyler 1987). Reindeer survive in the high Arctic principally by minimizing activity and energy expenditure, storing fat, and having excellent insulation (Nilssen 1984; Tyler 1987). The female Reindeer I observed trying to protect her calf maintained high physical activity for a relatively long period of time. However, the persistence of the fox probably caused the female Reindeer to become hyperthermic or exhausted. It is doubtful that this strategy would be as successful with the longer-legged Caribou/Reindeer of North America or Europe. Both Fine (1980) and Burgess (1984) reported several encounters between Caribou and Arctic Foxes in Alaska, and in one case a calf outdistanced a fox (Burgess 1984).

In contrast to Pink-Footed Geese, Barnacle Geese showed no active defensive behaviour, and usually fled to water when attacked by Arctic Foxes. In Svalbard, Barnacle Geese breed mainly on small islands which are not accessible to Arctic Foxes. A small portion of the population breeds inland, and nests on vertical cliffs where the fox cannot reach them. It appears that Barnacle Geese are vulnerable to fox predation when feeding away from open water. Speller (1968) observed Arctic Foxes killing adult Canada Geese (*Branta canadensis*) using the same method as I have described. Pink-Footed Geese were capable of defending their broods and nests from predation by the Arctic Fox, although their nest sites are found mainly at the edges of steep hills and are accessible to foxes. I rarely saw flocks of adults and gosling try to escape to water when foxes approached, even though lakes or the sea were nearby. Løvenskiold (1954) also reported that Pink-Footed Geese are able to protect their broods and nests from Arctic Foxes.

On several occasions Arctic Foxes stole prey from Glaucous Gulls and in each case the noise from the birds attracted the fox's attention. I also noted that foxes became alert when anxious geese fled their nests or nests sites due to human disturbance. It appears that foxes both relied on hearing and sight more than smell to locate prey than smell as concluded by Caley (1972).

In summary, Arctic Foxes in Svalbard are both skilled predators and scavengers. There were no significant differences in the diet of juveniles and adults, or between sexes. Reindeer, ptarmigan, alcids, fulmars and geese were the most important food sources. The method used by foxes to hunt Barnacle goslings, Purple Sandpiper chicks, and a Reindeer calf illustrate the importance of adaptation to local prey. The evolution of the ability to use a variety of foods, learn new hunting skills, and exploit local variation in prey availability are crucial to the survival of Arctic Foxes in the circumpolar Arctic. Fluctuations in the mortality of Reindeer and

in the density of ptarmigans may influence the Arctic Fox population dynamics.

Acknowledgments

I thank the trappers who provided carcasses for this study, especially L. Nielsen, H. Soleim, A. Midttømme, K. R. Hovelsrud, J. Sletten, O. Vik-Solheim and T. Grindhaug. Without assistance in the field from B. O. Frantzen, G. Bangjord, Ø. Pedersen, H.K. Drægni, E. Soglo and S. Bergheim, this project would not have been completed in its present form. Special thanks goes to I. Stirling for assistance and constructive criticism during preparation of the manuscript, and to the Canadian Wildlife Service, Edmonton, for providing me with office and support as a visiting scientist for a year while this study was written up. Thanks also to N. A. Øritsland for support during the whole project. I am grateful to N. J. C. Tyler, J. Black, L. Carbyn and A. Derocher for their constructive review of the manuscript. Funding for this project was provided by the Norwegian Polar Research Institute and the Norwegian Ministry of Environment. The Governor of Svalbard provided important logistic assistance.

Literature Cited

Bakken, V., and **F. Mehlum.** 1988. AKUP — Sluttrapport sjøfuglundersøkelser nord for N 74°/Bjørnøya (AKUP — Final report. Sea bird investigations north of 74°N/Bjørnøya). Norsk Polarinstitutt Rapportserie 44. (in Norwegian with english summary).

Birks, J. D. S., and **N. Penford.** 1990. Observations on the ecology of arctic foxes *Alopex lagopus* in Eqalummiut Nunaat, West Greenland. Meddelelser om Grønland. Bioscience 32: 3–26.

Braestrup, F. W. 1941. A study of the Arctic fox in Greenland. Meddelelser om Grønland 131: 1–101.

Burgess, R. M. 1984. Investigations of patterns of vegetation, distribution, and abundance of small mammals and nesting birds, and behavioral ecology of arctic foxes at Demarcation Bay, Alaska. M.S. thesis. University of Alaska, Fairbanks.

Caley, M. T. 1972. The ontogeny of predatory behaviour in captive arctic foxes. M.Sc. thesis. University of Alaska, Fairbanks. 25 pages.

Chesemore, D. L. 1968. Notes on food habits of arctic foxes in northern Alaska. Canadian Journal of Zoology 46: 1127–1130.

Eberhardt, L. E., W. C. Hanson, J. L. Bengtson, R. A. Garrott, and **E. E. Hanson.** 1982. Arctic fox home range characteristics in an oil development area. Journal of Wildlife Management 46: 183–190.

Fay, F. H., and **R. O. Stephenson.** 1989. Annual, seasonal, and habitat-related variation in feeding habits of the Arctic fox (*Alopex lagopus*) on St. Lawrence Island, Bering Sea. Canadian Journal of Zoology 67: 1986–1994.

Fine, H. 1980. Ecology of arctic foxes at Prudhoe Bay, Alaska. M.S. thesis. University of Alaska, Fairbanks.

Floyd, T. J., L. D. Mech, and **P. A. Jordan.** 1978. Relating wolf scat content to prey consumed. Journal of Wildlife Management 42: 528–532.

Fox, M. W. 1969. Ontogeny of prey-killing in *Canidae*. Behaviour 35: 259–272.

Garrott, R. A., L. E. Eberhardt, and **W. C. Hanson.** 1983. Summer food habits of juvenile arctic foxes in northern Alaska. Journal of Wildlife Management 47: 540–545.

Garrott, R. A., L. E. Eberhardt, and **W. C. Hansson.** 1984. Arctic fox denning behavior in northern Alaska. Canadian Journal of Zoology 62: 1636–1640.

Grue, H., and **B. Jensen.** 1976. Annual cementum structures in canine teeth in arctic foxes (*Alopex lagopus*) from Greenland and Denmark. Danish Review of Game Biology 10: 1–12.

Hersteinsson, P., and **D. W. Macdonald.** 1982. Some comparisons between red and arctic foxes, *Vulpes vulpes* and *Alopex lagopus*, as revealed by radio tracking. Symposia of the Zoological Society of London 49: 259–289.

Henry, J. D. 1980. Fox hunting. Natural History 89: 61–68.

Kennedy, A. J. 1980. Site variation in summer foods of Arctic fox on Prince of Wales Island, Northwest Territories. Arctic 33: 366–368.

Larson, S. 1960. On the influence of the arctic fox, *Alopex lagopus*, on the distribution of arctic birds. OIKOS 11: 276–305.

Lydersen, C., and **I. Gjertz.** 1986. Studies of the ringed seal (*Phoca hispida*) in its breeding habitat in Kongsfjorden, Svalbard. Polar Research 4: 57–63.

Løvenskiold, H. L. 1954. Studies of the avifauna of Spitzbergen. Norsk Polarinstitutt Skrifter 103: 1–131.

Macpherson, A. H. 1969. The dynamics of Canadian arctic fox populations. Canadian Wildlife Service Report Series Number 8.

Nilssen, K. 1984. Factors affecting energy expenditure in reindeer. Ph.D. thesis. University of Tromsø, Norway.

Prestrud, P. 1991. Adaptations by the arctic fox (*Alopex lagopus*) to the polar winter. Arctic 44: 132–138.

Prestrud, P., and **F. Mehlum.** 1991. Population size and summer distribution of common eiders (*Somateria mollissima*) in Svalbard. Norsk Polarinstitutt Skrifter 195: 9–20.

Prestrud, P., and **K. Nilssen.** 1992. Fat deposition and seasonal variation in body composition of arctic foxes in Svalbard. Journal of Wildlife Management 56: 221–233.

Quinlan, S. E., and **W. A. Lehnhausen.** 1982. Arctic fox, *Alopex lagopus*, predation on nesting Common eiders, *Sommateria mollissima*, at Icy Cape, Alaska. Canadian Field-Naturalist 96: 462–466.

Shibanoff, S. V. 1958. Dynamics of arctic fox numbers in relation to breeding, food and migration conditions. Translation of Russian Game Reports (Department of Northern Affairs and National Resources, Ottawa, Canada) 3: 5–28.

Smith, T. G. 1976. Predation of ringed seal pups (*Phoca hispida*) by the arctic fox (*Alopex lagopus*). Canadian Journal of Zoology 54: 1610–1616.

Speller, S. W. 1968. Arctic fox attacks on moulting Canada geese. Canadian Field-Naturalist 83: 62.

Speller, S. W. 1972. Food ecology and hunting behaviour of denning arctic foxes at Aberdeen Lake, Northwest Territories. Ph.D thesis. University of Saskatchewan, Saskatoon.

Stirling, I., and **T. G. Smith.** 1977. Interrelationship of arctic ocean mammals in the sea ice habitat. Pages 129–136 *in* Proceedings of the Circumpolar conference on northern ecology. National Research Council Canada, Ottawa.

Summers, R. W., and **L. G. Underhill.** 1987. Factors related to breeding production of brent geese *Branta b.*

bernicla and waders (*Charadrii*) on the Taimyr Peninsula. Bird Study 34: 161–171.

Tyler, N. J. C. 1987. Natural limitation of the abundance of the high arctic Svalbard reindeer. Ph.D. thesis. University of Cambridge, Cambridge.

Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Englewood cliffs, New Jersey.

Received 29 April 1991
Accepted 2 March 1992

Preliminary Evidence for Fractional Spawning by the Northern Redbelly Dace, *Phoxinus eos*

PERCE M. POWLES[1], S. FINUCAN[1], M. VAN HAAFTEN[1], and R. ALLEN CURRY[2]

[1]Department of Biology, Trent University, Peterborough, Ontario K9J 7B8
[2]Department of Zoology, University of Guelph, Guelph, Ontario N1G 2W1

Powles, Perce M., S. Finucan, M. van Haaften, and R. Allen Curry. 1992. Preliminary evidence for fractional spawning by the Northern Redbelly Dace, *Phoxinus eos*. Canadian Field-Naturalist 106(2): 237–240.

Field data on reproductive ecology of the Northern Redbelly Dace at Clear Lake, Ontario, over two years, 1984 and 1985, suggested that this species was a multiple or fractional spawner. The spawning season was long (mid-June to mid-August) and the density of larvae was low. We tested the hypothesis that the extended spawning season was caused by later maturation of small fish. Gonado-somatic indices for large and small dace showed the same seasonal pattern (0.15 end-June, and 0.07 end-July). Fecundity (mature eggs) estimates showed inconsistent relationships with lengths (r^2 = 0.01–0.72) and wide fluctuations in ranges, both of which are characteristics of fractional spawners. Egg diameter frequencies within the ovaries were bimodal, lending further support to our supposition that even in the more northern portion of its range, *Phoxinus eos* is a fractional spawner.

Key Words: Northern Redbelly Dace, *Phoxinus eos*, central Ontario, fractional spawning.

In recent years, fractional (also described as multiple, serial, or batch) spawning has been documented for many species of fish. This breeding strategy utilizes a series of spawning acts by an individual during an extended period. Such behaviour is more common in tropical species where the thermal limits on spawning periods are extended.

Gale and Buynak (1978, 1982) and Gale and Deutsch (1985) described fractional spawning behaviour in captive Satinfin Shiner (*Notropis analostanus*), Fathead Minnows (*Pimephales notatus*), and Tesselated Darters (*Etheostoma olmstedi*). Conover (1985) recorded batch fecundity in Silverside (*Menidia menidia*), and DeMartini and Fountain (1981) recorded batch fecundity of the Queenfish (*Seriphus politus*). Fractional spawning may also be inferred (but not verified) from the protracted spawning season of the Southern Redbelly Dace, *Phoxinus erythrogaster* (Settles and Hoyt 1978) and Blackside Dace, *Phoxinus cumberlandensis* (Starnes and Starnes 1981).

We suspected from field studies that Northern Redbelly Dace (*Phoxinus eos*) may also be fractional spawners. The only account of their spawning behaviour describes the extrusion of 5-30 eggs in one event observed by Cooper (1935). This account and our observations of an extended spawning period during which very low densities of post-larvae occurred in our study lake, suggested that Northern Redbelly Dace were fractional spawners. We hypothesized that fractional spawning would not occur if an extended spawning period was a function of younger/smaller fish maturing later in the season. Our objectives were to critically examine and compare between small and large dace the degree of maturation, fecundity, and egg diameter distributions within the population.

Methods

Clear Lake (Minden Township, Halton County, central Ontario) is a small (88 ha), oligotrophic lake with a mean depth of 12.4 m, pH range of 5.6–6.0 and mean alkalinity = 0.276 (TIA). Only four species of fish inhabit the lake: Northern Redbelly Dace, Yellow Perch (*Perca flavescens*), Creek Chub (*Semotilus atromaculatus*), and Lake Trout (*Salvelinus namaycush*).

Dace were sampled at various times from May to September, 1984 and 1985 (Table 1). They were captured with minnow traps, baited with "puppy chow", typically set overnight at depths of 1–3 m.

On each sampling occasion, 8–52 fish were preserved in formalin for egg counts. Sex, wet weight and total length were recorded for all fish. Ovaries of preserved fish were excised, blotted with paper towel, and weighed wet (nearest 0.01 g). Gonad analyses entailed: (1) measurements of egg diameters using an eyepiece micrometer (0.01 mm); (2) calculation of gonado-somatic index (GSI — ovary weight / total body weight) as in Snyder (1983); and, (3) assessment of maturity stages (immature, ripening, ripe/spawning, and spent). Three groups of eggs were categorized: immature ova, white with no yolk (0.1–0.6 mm); maturing ova, yellow, (0.5–0.9 mm); mature ova, yellow or sometimes transparent when hydrated (0.9–1.3 mm) following the methods of Conover (1985). Transparent ova were referred to as "ripe". Sometimes they were observed in pockets within the stroma of the ovary which usually appeared yellow. Ripe fish were considered those

TABLE 1. Summary of fecundity (mature eggs) data for redbelly dace. (r^2 represents regression of fecundity on length)

	DACE			EGGS				
Date	≤ 65 mm	> 65 mm	total	mean	s.d.	range	r^2	P
1984 21 June	9	3	12	331	91	182–500	0.72	<0.01
28 June	18	13	31	246	71	125–430	0.01	0.59
8 July	7	5	12	157	146	12–438	0.47	<0.01
23 July	6	15	21	194	78	72–342	0.61	<0.01
19 August	4	10	14	–	–	–	–	–
1985 29 May	6	10	16	327	128	168–546	0.23	0.05
8 June	0	9	9	366	117	217–552	0.01	0.08
20 June	19	33	42	–	–	–	–	–
13 July	0	8	8	293	55	212–361	0.25	0.20
26 July	18	23	31	127	63	26–320	0.15	0.03

which contained mainly large eggs (> 1.0 mm) or pockets of transparent eggs. Immature ovaries were those which contained no eggs with yellow yolk.

We determined that small fish would be considered ≤ 65 mm and large fish > 65 mm based on an apparent natural separation of lengths among collected dace. GSI measures are presented from 1984 and egg size distribution from 1985. Simple linear regression was utilized for the fecundity analysis on the data collected in 1985.

Results

In both years, the spawning season extended from June through July with most fish still maturing in May, and spent by the middle of August. Plots of the GSI by size groups in 1984 displayed a gradual rise through 28 June, with peak ovary weight occurring in late June and early July (Figure 1). Values then declined, confirming that fish were spent by mid-August. Seasonal patterns of the GSI were similar for both size classes of dace.

Regressions of fecundity on total length revealed no consistent relationship between numbers of eggs and size of dace (Table 1).

Diameters of maturing and mature eggs followed a bimodal distribution in May and June for both small and large dace (Figure 2). A lower proportion of mature eggs (> 1.0 mm) was observed as July progressed.

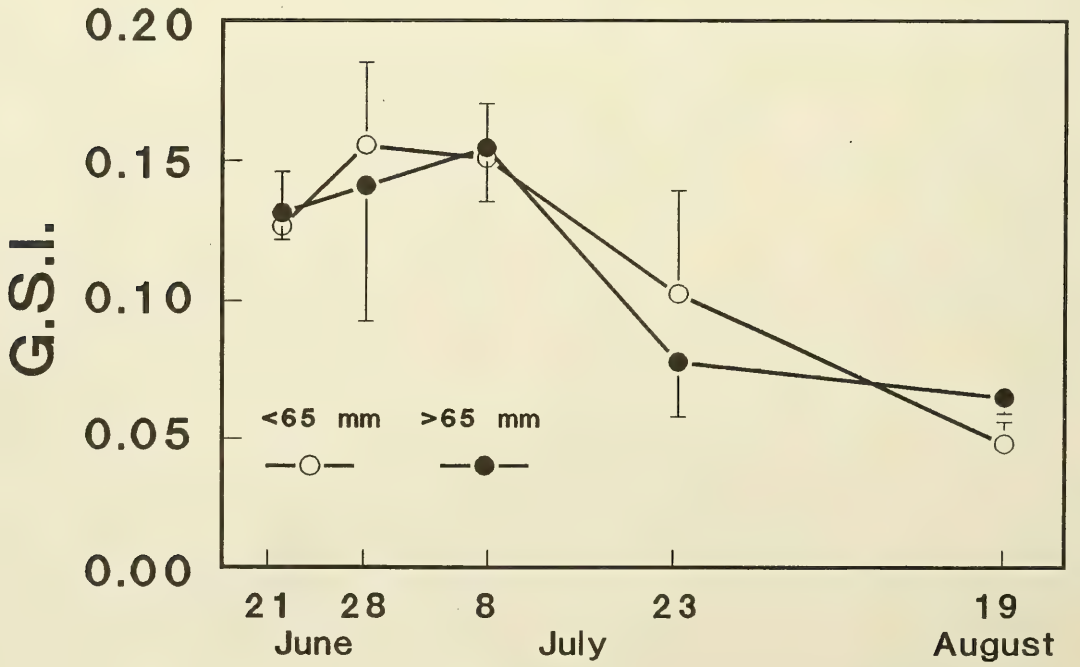


FIGURE 1. Gonado-somatic indices (GSI) for Northern Redbelly Dace in 1984. Error bars are one standard deviation.

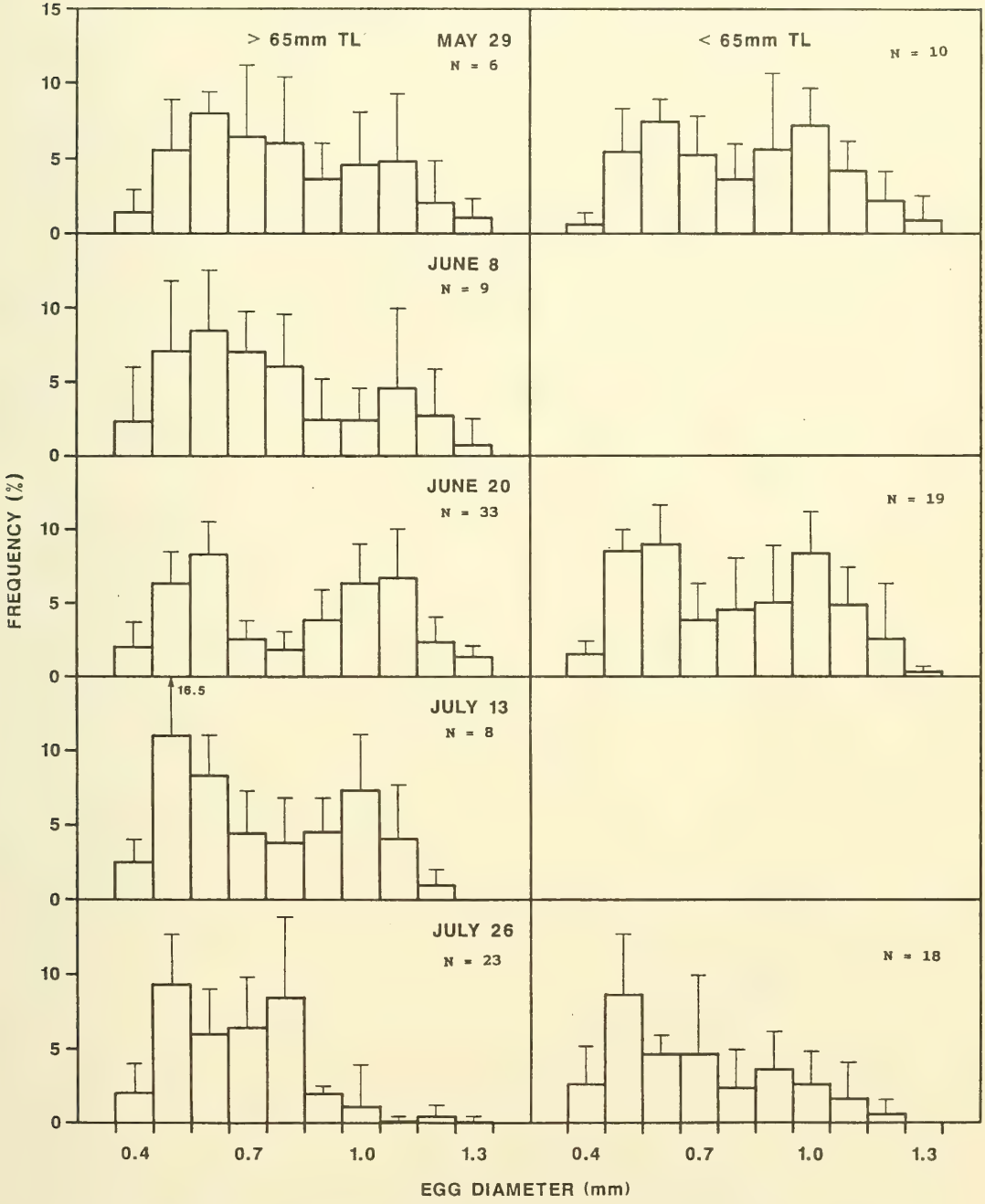


FIGURE 2. Frequency distribution of egg diameters (excluding recruitment ova) in: a) May, b) June, and c) July, 1985 for Northern Redbelly Dace. Error bars are one standard deviation.

Discussion

The similarity of change in the GSI over time among all size groups indicated that late maturation (or recruitment to the spawning stock) of smaller dace did not account for the extended spawning season. Southern Redbelly Dace also spawn over a long period, from April to June (Settles and Hoyt 1978). The closely-related Finescale Dace (*Phoxinus neogaeus*) spawns for just over a month (Stasiak 1978). Finescale Dace can hybridize with Northern

Redbelly Dace and inhabit other lakes in our region. This was a potentially confusing factor for our observations of spawning ecology, however, our Clear Lake dace did not appear to include hybrids according to the main morphological criteria used by Das and Nelson (1988).

Significant changes in relationships between fecundity and length of fish would be predicted if smaller/younger fish were being recruited to the spawning stock as the season progressed. Specifically, a positive relationship would exist during the early spawning (large fish with high numbers of eggs and small fish with low numbers of eggs) and a negative relationship during late spawning (fewer eggs for large fish, more for small fish). There were no such relationships for Northern Redbelly Dace data of Clear Lake, thus lending support to our fractional spawning postulation.

The bimodal distribution of egg sizes in both small and large fish early in the season suggested that more than one spawning event occurred. The largest eggs (> 0.9 mm) were ripe and ready for ovulation with the smaller eggs (0.5–0.9 mm) still maturing. The proportion of large, mature eggs was reduced in July, indicating peak spawning activities during this period.

We were unable to estimate the batch fecundity in the manner suggested by Conover (1985), as we lacked seasonal counts of recruitment eggs (< 0.5 mm). Also, since our captive redbelly dace did not spawn, we could not establish a fraction spawned in one event. We agree with Cooper (1935) that a number like 20–30 eggs are probably spawned in one event, which is similar to the number observed for Finescale Dace (Stasiak 1978). Occasional observations by us of 10–30 transparent eggs in ovaries supports this hypothesis. Since we did not observe hydrated eggs very often, it is probable that ripening proceeds rapidly with spawning occurring at night. Naud and Magnon (1987) have shown that Northern Redbelly Dace are nocturnal foragers.

The protracted spawning period, patterns of fecundity to size relationships, and egg size distributions with no apparent age (size) differentiation, indicated the Northern Redbelly Dace in Clear Lake at least, are fractional spawners. This represents one more cyprinid species that utilizes an apparently atypical breeding strategy compared to most north temperate fish. Such a strategy suggests a selection for increased fecundity while maintaining small body size and greater survival of young resulting from their increased temporal dispersal. If indeed global warming continues, production and northern distribution of Northern Redbelly Dace should increase as the occurrence of favourable reproduction temperatures for this species is extended northward.

Acknowledgments

We wish to acknowledge with thanks, the members of the Biology Department who assisted with this project, particularly Wayne Wilson, Jim Nighswander and Nakos Kotsanis. Stan Warlen also assisted with SCUBA attempts at *in situ* observations of spawning. National Science and Engineering Research Grant #A2353 to PMP supported much of the research.

Literature Cited

Conover, D. O. 1985. Field and laboratory assessment of patterns in fecundity of a multiple spawning fish: the Atlantic silverside *Menidia menidia*. Fisheries Bulletin 83: 331–341.

Cooper, G. P. 1935. Some results of forage fish investigations in Michigan. Transactions of the American Fisheries Society 65: 132–142.

Das, M. K., and **J. S. Nelson.** 1988. Hybridization between northern redbelly dace (*Phoxinus eos*) and finescale dace (*Phoxinus neogaeus*) (Osteichthyes: Cyprinidae) in Alberta. Canadian Journal of Zoology 67: 579–584.

DeMartini, E. C., and **R. K. Fountain.** 1981. Ovarian cycling frequency and batch fecundity in the queenfish, (*Seriphus politus*: Attributes representative of serial spawning fishes. Fisheries Bulletin 79: 547–560.

Gale, W. F., and **G. Buynak.** 1978. Spawning frequency and fecundity of the satinfin shiner (*Notropis analostanus*) — a fractional, crevice spawner. Transactions of the American Fisheries Society 107: 460–463.

Gale, W. F., and **G. Buynak.** 1982. Fecundity and spawning frequency of the fathead minnow — a fractional spawner. Transactions of the American Fisheries Society 111: 35–40.

Gale, W. F., and **W. Deutsch.** 1985. Fecundity and spawning frequency of captive tesselated darters — fractional spawners. Transactions of the American Fisheries Society 114: 220–229.

Naud, M., and **P. Magnon.** 1987. Diel onshore-offshore migrations in northern redbelly dace, *Phoxinus eos* (Cope), in relation to prey distribution in a small oligotrophic lake. Canadian Journal of Zoology 66: 1249–1253.

Settles, W. H., and **R. D. Hoyt.** 1978. The reproductive biology of the southern redbelly dace, *Chrosomus erythrogaster* Rafinesque, in a spring-fed stream in Kentucky. American Midland Naturalist 99: 290–298.

Snyder, D. E. 1983. Fish eggs and larvae. Pages 165–167 *in* Fisheries Techniques. *Edited by* L. A. Nielsen and D. L. Johnson. American Fisheries Society, Bethesda, Maryland.

Starnes, L. B., and **W. C. Starnes.** 1981. Biology of the blackside dace, *Phoxinus cumberlandensis*. American Midland Naturalist 106: 360–371.

Stasiak, R. H. 1978. Reproduction, age and growth of the finescale dace, (*Chrosomus neogaeus*), in Minnesota. Transactions of the American Fisheries Society 107: 720–723.

Received 13 May 1991
Accepted 24 February 1992

Ontogenetic Changes in Habitat Use by Juvenile Turtles, *Chelydra serpentina* and *Chrysemys picta*

JUSTIN D. CONGDON[1], STEVE W. GOTTE[2] and ROY W. MCDIARMID[2]

[1]Savannah River Ecology Laboratory, Drawer E, Aiken, South Carolina 29801
[2]Biological Survey, US Fish and Wildlife Service, National Museum of Natural History, Washington, D.C. 20560

Congdon, Justin D., Steve W. Gotte, and Roy W. McDiarmid. 1992. Ontogenetic changes in habitat use by juvenile turtles, *Chelydra serpentina* and *Chrysemys picta*. Canadian Field-Naturalist 106(2): 241–248.

During a 10-year period approximately 1600 turtles were captured and 9500 recaptured in East Marsh on the E. S. George Reserve in southeastern Michigan. Analysis of the marsh depth at point of capture indicates that younger and smaller juvenile Snapping Turtles (*Chelydra serpentina*) and Painted Turtles (*Chrysemys picta*) were more likely than older and larger juveniles to be captured in shallow portions of the marsh. A relationship of increased water depth with turtle size and age continued through to sexual maturity. Hatchlings and one-year-old individuals occupied significantly shallower portions of the marsh than did all other size categories. By resticting their activity to shallow water near shore, younger and smaller turtles may increase their foraging success and reduce the probability of encountering large fish or adult turtle predators.

Key Words: Snapping Turtle, *Chelydra serpentina*, Painted Turtle, *Chrysemys picta*, habitat selection, juveniles, marsh depth.

Organisms produce offspring that are either very different in appearance from the adults, or that appear to be miniature adults. In organisms with complex life cycles, requirements of offspring are obviously different from those of adults (e.g., most frog larvae are aquatic herbivores, whereas adults are terrestrial predators). In contrast, organisms such as lizards and turtles produce young that are essentially miniature adults. Although less profound than the developmental changes observed in organisms with complex life cycles, differences in body size alone may also result in differences in both habitat requirements and diets of juveniles and adults. Differential habitat use associated with age or size of juveniles may result from changes in diet, distributions of food resources of appropriate sizes, size specific risks of predation, or a combination of these factors. Compared to adults, hatchlings of some freshwater turtles are found in shallow or more vegetated portions of marshes (*Emydoidea blanghgii*: Pappas and Brecke 1992), quiet or backwater portions of rivers (*Trachemys scripta*: Moll and Legler 1971; Hart 1983; *Trionyx muticus*: Plummer 1977; *Graptemys nigrinoda*: Lahanas 1982) or protected backwater sections and oxbow lakes (*G. nigrinoda*: Lahanas 1982). In addition, ontogenetic shifts in diet from carnivory as juveniles to primarily herbivory as adults has been reported for the Slider Turtle (*Trachemys scripta*: Clark and Gibbons 1969; Moll and Legler 1971; Hart 1983; Parmenter and Avery 1990), Ouachita Map Turtle (*Graptemys ouachitensis*: Moll 1976), Cooter (*Pseudemys floridana*: Bancroft et al. 1983), and Kefts River Turtle (*Emydura krefftii*: Georges 1982). Age related changes in diets in freshwater turtles suggest, but do not require, that associated changes in habitat use also occur during growth from hatchling to adult stages.

Because of difficulties in capturing hatchlings and small juveniles, most ecological and life history studies of freshwater turtles have concentrated on adults. As a result, the following questions remain: (1) are ontogenetic shifts in habitat use of sufficient magnitude to be considered important, and (2) are ontogenetic shifts in habitat use a widespread phenomenon? Previous studies of life histories of Snapping Turtles (*Chelydra serpentina*) and Painted Turtles (*Chrysemys picta*) (Congdon and Gatten 1989) on the E. S. George Reserve present an opportunity to examine the relationships between ages and sizes of juvenile turtles and marsh depth at the point of capture.

Materials and Methods

This study was conducted on the University of Michigan's E. S. George Reserve, Livingston County, Michigan (approximately 42°28'N, 84°00'W). Detailed descriptions of the habitats on the E. S. George Reserve are in Cantrall (1943), Sexton (1959), Wilbur (1975), Collins and Wilbur (1979), Congdon et al. (1986), and Congdon and Gibbons (1989). About 4.0 ha of water in East Marsh are deep enough to trap; an additional 1.5 ha of seasonally inundated wetland contain grass hummocks interspersed with shallow and narrow water channels. A grid system established in East Marsh in 1977 has marker stakes every 8 m in an X, Y array. In June of 1988, we measured water depth at all 117 grid stakes in East Marsh. Maximum water depth was about 90 cm; however, 70% of the marsh was less than 50 cm in depth (Figure 1).

Except during some nesting seasons when trapping was temporarily suspended, intensive aquatic trapping of East Marsh began in early May and con-

tinued through mid-September each year from 1977 through 1986. Turtle traps were either 80, 120 or 140 cm in diameter and consisted of three metal hoops overlain with 3.9 cm webbing which formed a funnel opening at one end. All sizes and types of traps caught all sizes of turtles except the smallest hatchlings. A minimum of 55 traps baited with fish or whole kernel corn were placed throughout East Marsh and trap locations were changed at approximately two week intervals. In addition, each year about 10 unbaited fyke and 15 drift traps were also placed in the marsh. These sets remained in place for the summer. Fyke sets consisted of 10 m long V-shaped wings made of 3.9 cm mesh netting suspended between floats and sinkers and attached directly to unbaited traps. Drift sets consisted of 15 m of netting suspended between floats and sinkers that was stretched between stakes to make an aquatic drift fence with unbaited traps at each end. Thus, about 80 traps were used in East Marsh each year; however, in 1985 and 1986 an extra 30 were set for the entire trapping season (see Congdon et al. 1983, 1987; Congdon and van Loben Sels 1991; for details about other capture methods).

About 1150 Painted Turtles (7200 recaptures) and 450 Snapping Turtles (885 recaptures) have been recorded in East Marsh. Data for the primary analyses for this study were restricted to six years from 1980 through 1986. Data from the years prior to 1978 were excluded because of lower trapping effort and data from 1978, 1979, and 1984 were excluded because of very low water levels during drought (see later discussion). Each captured turtle was individually marked, weighed, straight line plastron length (PL) and carapace length (CL) measured, and released at the grid stake nearest to the point of capture. If possible, the sex of each individual was determined from external examination. Complete measurements and weights of recaptured turtles were usually taken at the first recapture each year and again at the end of the activity season during September and October.

Because most older Snapping Turtles were of unknown age, all Snapping Turtles were first assigned to four categories: (1) adult males, (2) adult females, (3) medium-sized juveniles [CL from 101 — 249 mm], and (4) small juveniles [CL < 101]. Marsh depths at point of capture were initially compared among the four categories.

Ages of many of the turtles were obtained by marking hatchlings at nests or at drift fences as they moved from nests to marshes (Congdon et al. 1987). We selected the minimum known age for nesting females as the upper limit for juvenile categories. Ages of Snapping Turtles not marked as hatchlings, but below 12 years of age (minimum age at nesting), were determined from growth rings. Male Snapping Turtles at the minimum body size of nesting females (200 mm CL) averaged 10 years of age. Painted Turtles that were first captured with fewer than 9 (females) or 6 (males) growth rings were assigned an age based on the number of growth rings. Aging of both species from growth rings was based on the assumption that visible growth rings were laid down annually in juveniles and young adults. Sequential recaptures of juveniles of both species over all age classes during the past 15 years support this assumption. The data sets restricted to only known aged individuals were sufficient to analyze capture location depths for Snapping Turtles less than 13 years of age. Age data were sufficient for all samples of juvenile Painted Turtles prior to the minimum age at sexual maturity of females at age 7. Therefore, all analyses of marsh depths in Painted Turtles were based on age rather than size.

When dealing with recaptures of individuals, problems with independence of observations may occur. Minimum recapture intervals were set for each species based on the assumption that either species can easily traverse the entire marsh within seven days. The much larger data set on *C. picta* allowed a 14 day recapture interval while maintaining adequate sample sizes. Therefore, recaptures less than 8 days apart for Snapping Turtles and 15 days apart for Painted Turtles were excluded from analyses.

All ANOVA results used Type III sums of squares, and differences among means were determined using Duncan's Multiple Range Tests (MRT). Otherwise, the non-parametric Kruskall-Wallis (KW) Test was used (SAS Institute 1988). Unless otherwise stated, levels of significance were accepted at alpha < 0.05. Measures of central tendency and dispersion are presented as the mean ± one standard error unless stated otherwise.

Results

Both size and body mass of Snapping Turtles increase rapidly from hatching through age 12, the age at which females approach sexual maturity (Table 1; Congdon et al. 1987). Analysis of water depth in East Marsh at the site of capture of individuals of all four size categories indicated significant differences among groups (ANOVA; $F_{3,375}$ = 7.77, P = 0.0001). Small juveniles occupied significantly shallower water (37.6 cm) than did the other three categories (50.9 cm; MRT; $P < 0.05$). The differences in body size categories, based on parametric statistics, were confirmed by a non-parametric analysis (KW Test; Df = 3, P = 0.0004). In addition, age effects were analyzed for individuals below the age of 13. Snapping Turtles of different ages were captured at different water depths (ANOVA; $F_{11,103}$ = 2.25, P = 0.017). Older Snapping Turtles were not trapped consistently in greater mean water depths (MRT; $P > 0.05$); however, the youngest turtles were captured in the shallowest water (MRT; $P < 0.05$). Similar results were also found using a non-parametric analysis (KW

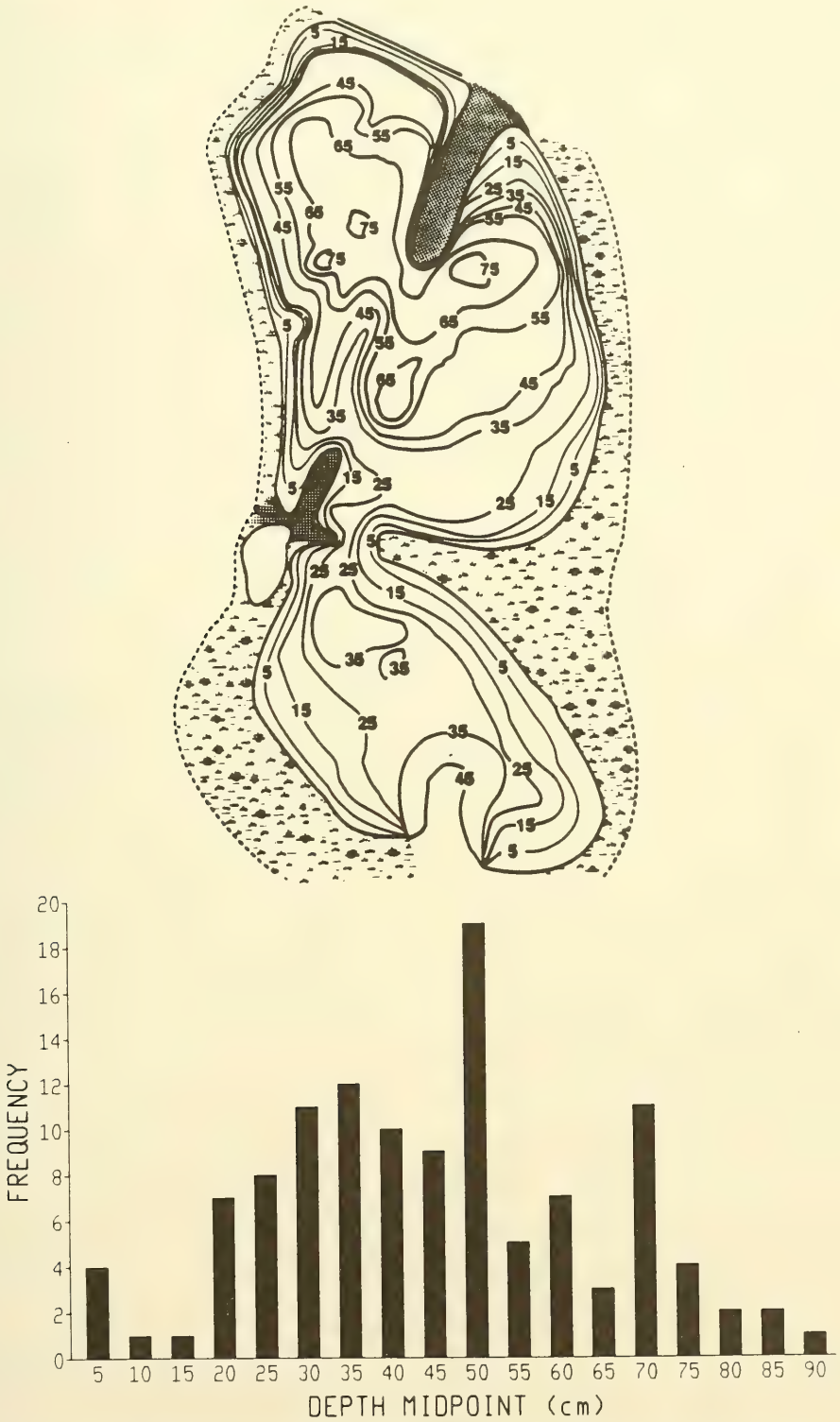


FIGURE 1. Depth contours in cm and frequency histogram of water depths (cm) in East Marsh on the E. S. George Reserve in southeastern Michigan.

TABLE 1. Sizes and body masses of juvenile and young adult Snapping Turtles of known age from all aquatic areas on the E. S. George Reserve [data include means and (1SE)].

Age	N	Carapace length (mm)	Plastron length (mm)	Weight (g)
0	871	29.6 (0.06)	22.1 (0.05)	9.1 (0.05)
1	43	33.8 (1.60)	25.5 (1.31)	15.0 (2.02)
2	38	67.8 (1.88)	52.3 (1.40)	85.7 (7.86)
3	70	86.4 (1.88)	65.6 (1.41)	177.3 (12.20)
4	61	106.3 (3.71)	81.3 (2.83)	364.5 (51.79)
5	56	122.8 (3.93)	93.8 (3.10)	552.0 (68.55)
6	65	139.6 (3.33)	105.5 (2.74)	751.4 (57.46)
7	47	166.0 (4.08)	124.7 (2.91)	1215.5 (90.82)
8	53	173.8 (3.91)	131.1 (3.00)	1341.9 (98.76)
9	33	188.6 (3.60)	142.0 (2.40)	1657.1 (92.24)
10	41	197.2 (3.57)	148.3 (2.59)	1949.4 (103.07)
11	25	218.3 (4.41)	163.6 (3.46)	2492.5 (139.62)
12	26	220.1 (3.18)	167.3 (2.84)	2503.6 (122.49)

Test; $Df = 11$, $P = 0.027$). Marsh depth at point of capture had a positive linear relationship with mean age of turtles captured (Figure 2).

Painted Turtles showed similar relationships of age to marsh depth. Males and females below the age of six years increased in size and body mass (Table 2a,b). However, growth slows as males approach maturity at age four, whereas growth of females does not slow until they reach minimum age at sexual maturity at age seven (Sexton 1959; Gibbons 1968; Ernst 1971; Wilbur 1975; Tinkle et al. 1981). Painted Turtles of different ages were captured at significantly different water depths (ANOVA; $F_{5,54} = 2.99$, $P = 0.019$). Mean water depth at the point of capture increased in the following rank order by age: two, one, three, four, six, and five years. Water depth at age two was not different from those at ages one and three (MRT; $P > 0.05$), but was significantly different from those for ages four and older (MRT; $P < 0.05$). Similar age differ-

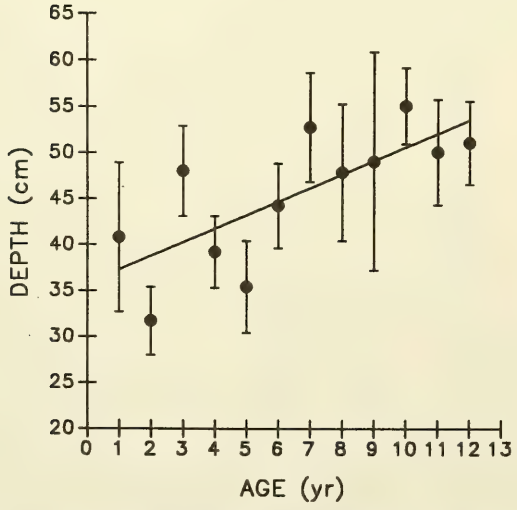


FIGURE 2. The relationship between Snapping Turtle age and mean water depth at point of capture of juvenile Snapping Turtles in East Marsh between 1980 and 1986. Linear regression statistics; depth = 35.8 + 1.47 * age, $SE = 0.36$, $N = 12$, $R^2 = 0.54$, $F_{1,11} = 11.75$, $P = 0.006$.

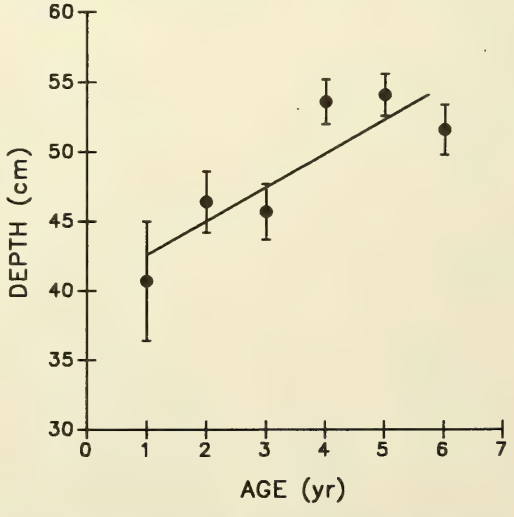


FIGURE 3. The relationship between Painted Turtle age and mean water depth at point of capture of juvenile Painted Turtles in East Marsh between 1980 and 1986. Linear regression statistics; depth = 40.1 + 2.45 * age, $SE = 1.41$, $N = 6$, $R^2 = 0.75$, $F_{1,5} = 11.82$, $P = 0.02$.

TABLE 2. Sizes and body masses of Painted Turtles of known age from East Marsh on the E. S. George Reserve [data include means and (1SE)].

(a) Juvenile and young adult males Age	N	Carapace length (mm)	Plastron length (mm)	Weight (g)
0	394	24.6 (0.09)	22.9 (0.09)	3.7 (0.03)
1	20	56.4 (2.00)	50.8 (1.75)	34.2 (3.22)
2	55	72.3 (0.96)	65.6 (0.96)	63.2 (2.17)
3	37	87.6 (1.43)	80.2 (1.44)	105.3 (5.18)
4	30	95.6 (1.15)	87.8 (1.02)	125.2 (4.01)
5	36	99.8 (1.09)	91.4 (0.92)	138.0 (4.08)
6	16	105.1 (2.25)	95.8 (2.21)	151.1 (9.24)

(b) Juvenile females Age	N	Carapace length (mm)	Plastron length (mm)	Weight (g)
0	394	24.6 (0.09)	22.9 (0.09)	3.7 (0.03)
1	20	62.3 (1.25)	56.6 (1.14)	43.4 (2.83)
2	42	76.3 (0.97)	69.8 (0.93)	74.0 (2.31)
3	37	88.1 (1.88)	81.3 (1.83)	109.1 (7.68)
4	41	97.2 (1.53)	89.9 (1.55)	138.5 (6.08)
5	32	105.5 (1.94)	98.3 (1.88)	172.3 (9.53)
6	28	115.5 (2.69)	107.5 (2.71)	222.0 (14.63)

ences associated with water depths were also found using non-parametric tests (KW Test; $Df = 5$, $P = 0.005$). The linear relationship of water depth with age was also positive (Figure 3).

Because our measure of water depth was static (i.e., it did not change as actual water depth changed throughout the summer), we analyzed the data on Painted Turtles with year and age as class variables and day of year (DOY) as a covariate. The water depth at point of capture was different for different years (ANCOVA; $F_{5,700} = 4.44$, $P = 0.0001$), ages ($F_{5,700} = 3.13$, $P = 0.008$), and for DOY ($F_{1,700} = 7.40$, $P = 0.007$) and DOY * YR interactions ($F_{5,700} = 5.45$, $P = 0.0001$).

Discussion

Female Snapping Turtles on the ESGR reach sexual maturity at a minimum age of 12 years (Congdon et al. 1987). Snapping Turtles increase in CL about 8 times and in body mass about 279 times between hatching and age 12 (Table 1). The only significant difference in average marsh depth associated with captures of four size categories of Snapping Turtles was between the smallest turtles and all other categories. However, as age and size of juveniles increased, the average marsh depth at point of capture also increased; these results indicate that although the major depth changes associated with size or age occur between the youngest and all subsequent age or size classes, more gradual changes in marsh depth at the capture site occur among the older juveniles (Figure 2).

The increase in size among Painted Turtle juveniles is less profound (Table 2a,b) than in Snapping Turtles. By the time male Painted Turtles mature at a minimum age of four years, they have increased CL and body mass by approximately 4 and 34 times, respectively. Female Painted Turtles mature at a minimum age of seven years; by age six they have increased 5 times in CL and 60 times in body mass. The pattern of changes in marsh depth associated with capture locations of Painted Turtle juveniles was similar to that found in Snapping Turtles. However, the slope of the relationship of age with water depth was steeper for Painted Turtles (2.46) than for Snapping Turtles (1.47; non overlap of 2SE). The three youngest age groups of Painted Turtles were trapped at shallowest mean water depths in East Marsh and the three older age groups in the deepest water.

Snapping Turtles through age six were caught in shallower water than were Painted Turtles of the same age. The difference between the species may be related to foraging modes. Snapping Turtles apparently ambush prey while resting on the bottom, whereas Painted Turtles seem to forage more actively in the surface vegetation and possibly throughout the water column.

As expected in any shallow marsh, the relationships among turtle ages (sizes), years, day of the year and water depth are dynamic. Changes may occur seasonally with the social environment, with the development of aquatic vegetation during spring, or as water levels are maintained or increase with

rainfall or decrease during dry periods when evaporation exceeds water input to the marsh.

We also examined marsh depth at point of capture during drought years. The slope of the relationship between size or age of turtles and marsh depth during these years was either zero or negative. The differences between drought years and years of normal water level were in part due to our static measure of marsh depth and the rapid drop in water level during the trapping period (i.e., areas that were initially "deep" rapidly became "shallow").

Although we have no data to indicate why juveniles of different ages or sizes of either species were captured in different depths of water, the distribution of appropriate food resources, swimming abilities of juveniles, differences in thermal preferences, social interactions, and predator avoidance may all be involved. Hart (1983) noted that in *Trachemys scripta elegans* in Louisiana, increasing feeding depths paralleled increasing body size and consumption of plants. Painted Turtles have been reported to be primarily carnivorous as juveniles and become increasingly herbivorous with age and size (Sexton 1959). Appropriately sized invertebrate prey may be more abundant or more catchable by juveniles in shallower compared to deeper water, or plants preferred as food by adults may be more common in deeper water.

Active turtles need to surface periodically to breathe. Hatchlings and smaller juveniles of Snapping Turtles are poor swimmers compared to adults (Hammer 1969). Younger turtles may simply stay in shallower water until they develop swimming skills that more easily allow them to reach the surface in deep water.

Because water warms faster in shallow than in deep areas, thermal preferences may be involved in depth choice by turtles. Adult turtles often spend more time in shallow and presumably warmer waters in the early spring and then move to deeper areas as water temperatures rise (Sexton 1959 for Painted Turtles in Michigan; Hart 1983 for Sliders in Louisiana). Hatchling *Trionyx muticus* were more frequent in warmer, quieter water in shallow areas or on the lee of sandbars than in surrounding habitats (Plummer 1977). Growth in Sliders (Gibbons 1970; Christy et al. 1974; Thornhill 1982) and Snapping Turtles (Williamson et al. 1989) is faster at warmer temperatures. Parmenter and Avery (1990) hypothesized that elevated body temperatures and the concomitant increased growth rates result in earlier attainment of sexual maturity in turtles. With faster growth, hatchlings and small juveniles would reach a larger size sooner and thereby be less vulnerable to predation.

As adults, Snapping Turtles may be able to function more effectively at cooler temperatures than Painted Turtles. Snapping Turtles have lower critical thermal maxima (Hutchison et al. 1966) and faster digestive turnover rates (Parmenter 1981) than do Painted Turtles; however, both species showed similar patterns of habitat use in this study. The similarity of pattern suggests that the use of shallow water by juveniles is based on common benefits that juveniles accrue by restricting most of their activity to shallower portions of the marsh.

Little is known about social interactions or age/size dependent behavior in most turtle species including Snapping Turtles and Painted Turtles. Territoriality and other forms of behavioral hierarchies affect dispersion and could produce the kind of habitat segregation reported in this study. Certainly the social environment of juveniles is different from that of adults in both species.

Although age specific mortality schedules of juvenile turtles are few, predator avoidance, including cannibalism, may be an important component in differences in habitat use by individuals of different age and size. Predators capable of taking the smallest sizes of hatchlings and juveniles include mink, otters, raccoons, wading birds, birds of prey, crows, large fish, aquatic snakes, and large bodied turtles. Werner and Hall (1988) presented evidence that juvenile Bluegills (*Lepomis macrochirus*) used shallow, vegetated portions of several Michigan lakes, whereas the adults frequented deeper and more open habitats. Werner and Hall (1988) argued that this pattern resulted from a trade-off between foraging rate (better in open water) and predation risk (higher in open water). As Bluegill approached the size that was too large for easy consumption by bass, individuals moved into deeper water. By restricting their activity to the more shallow portions of East Marsh, small turtles may also avoid predators such as fishes and larger turtles that occupy the deeper areas. However, in doing so, they may increase their vulnerability to predators such as wading birds and raccoons that feed in the shallows. Hart (1983) suggested that juvenile turtles may stay in shallow areas until increasing body size decreases their ability to hide, or vegetation density impairs their ability to escape predators, at which point they move to deeper water.

The findings from this study support the idea that: 1) as juvenile turtles grow older they tend to be found in deeper water, and 2) the phenomenon is widespread among turtles since shifts to deeper water occurred in both Painted Turtles (family Emydidae) and Snapping Turtles (family Chelydridae). Future studies should be designed to determine the reasons for ontogenetic changes in habitat use by juveniles. More detailed studies are necessary to enhance our understanding of the constraints and risks associated with resource acquisition by juveniles. Knowledge of how habitat variability influences juvenile success, population stability and species persistence is critical for conservation and management of turtle populations.

Acknowledgments

The following people made substantial contributions to this study: Harold and Sue Avery, Margaret Burkman, Matthew Hinz, Mark Hutcheson, Tal Novak, John Stegmeir, Richard van Loben Sels, and Richard, John and Bradley Wiltse. Many aspects of the long-term study on the E. S. George Reserve were made possible by the University of Michigan's Museum of Zoology, the E. S. George Reserve Committee, and the enthusiastic support of the maintenance crew. Earlier drafts of the manuscript were improved by comments from J. Whitfield Gibbons and Robert P. Reynolds. Funding for this study was provided by National Science Foundation grants DEB-74-070631, DEB-79-06301, and BSR-84-00861 and by the US Fish and Wildlife Service. Editing of computer files, data analysis, and manuscript preparation were aided by contract DE-AC09-76SROO-819 between the University of Georgia and the United States Department of Energy.

Literature Cited

Bancroft, G. T., J. S. Godley, D. T. Gross, N. N. Rojas, D. A. Sutphen, and **R. W. McDiarmid.** 1983. Large-scale operations management test of use of white amur for control of problem aquatic plants: The herpetofauna of Lake Conway, Florida: species accounts. Miscellaneous Paper A-83-5, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Mississippi.

Cantrall, I. J. 1943. The ecology of the Orthoptera and Dermaptera of the E. S. George Reserve, Michigan. Miscellaneous Publications of the Museum of Zoology, the University of Michigan 54: 1–182.

Christy, E. J., J. O. Farlow, J. E. Bourque, and **J. W. Gibbons.** 1974. Enhanced growth and increased body size of turtles living in thermal and post-thermal aquatic systems. Pages 277–284 *in* Thermal Ecology. *Edited by* J. W. Gibbons and R. R. Sharitz. U. S. Atomic Energy Commission Symposium Series (CONF-730505). Nature and Technology Information Service, Springfield, Virginia.

Clark, D. B., and **J. W. Gibbons.** 1969. Dietary shift in the turtle *Pseudemys scripta* (Schoepff) from youth to maturity. Copeia 1969: 704–706.

Collins, J. P., and **H. M. Wilbur.** 1979. Breeding habits and habitats of the amphibians of the Edwin S. George Reserve, Michigan, with notes on the local distribution of fishes. Occasional Papers of the Museum of Zoology, the University of Michigan 868: 1–34.

Congdon, J. D., G. L. Breitenbach, R. C. van Loben Sels, and **D. W. Tinkle.** 1987. Reproduction and nesting ecology of snapping turtles (*Chelydra serpentina*) in southeastern Michigan. Herpetologica 43: 39–54.

Congdon, J. D., and **R. E. Gatten.** 1989. Movements and energetics of nesting *Chrysemys picta*. Herpetologica 45: 94–100.

Congdon, J. D., and **J. W. Gibbons.** 1989. Biomass productivity of turtles in freshwater wetlands: A geographic comparison. Pages 583–592. *in* Freshwater Wetlands and Wildlife. *Edited by* R. R. Sharitz and J. W. Gibbons. CONF-8603101, DOE Symposium Series Number 61. US Department of Energy, Office of Science and Technology Information, Oak Ridge, Tennessee.

Congdon, J. D., J. L. Greene, and **J. W. Gibbons.** 1986. Biomass of freshwater turtles: A geographic comparison. American Midland Naturalist 115: 165–173.

Congdon, J. D., D. W. Tinkle, G. L. Breitenbach, and **R. C. van Loben Sels.** 1983. Nesting behavior and nesting success in the turtle *Emydoidea blandingi*. Herpetologica 39: 417–429.

Congdon, J. D., and **R. C. van Loben Sels.** 1991. Growth and body size variation in Blanding's turtles (*Emydoidea blandingi*): relationships to reproduction. Canadian Journal of Zoology 69: 239–245.

Ernst, C. H. 1971. Sexual cycles and maturity of the turtle, *Chrysemys picta*. Biological Bulletin 140: 191–200.

Georges, A. 1982. Diet of the Australian freshwater turtle *Emydura krefftii* (Chelonia: Chelidae), in an unproductive lentic environment. Copeia 1982: 331–336.

Gibbons, J. W. 1968. Reproductive potential, activity, and cycles in the painted turtle, *Chrysemys picta*. Ecology 49: 399–409.

Gibbons, J. W. 1970. Reproductive dynamics of a turtle (*Pseudemys scripta*) population in a reservoir receiving heated effluent from a nuclear reactor. Canadian Journal of Zoology 48: 881–885.

Hammer, D. A. 1969. Parameters of a marsh snapping turtle population, LaCreek Refuge, South Dakota. Journal of Wildlife Management 33: 995–1005.

Hart, D. R. 1983. Dietary and habitat shift with size of red-eared turtles (*Pseudemys scripta*) in a southern Louisiana poulation. Herpetologica 39: 285–290.

Hutchison, V. H., A. Vinegar, and **R. J. Kosh.** 1966. Critical thermal maxima in turtles. Herpetologica 22: 32–41.

Lahanas, P. N. 1982. Aspects of the life history of the southern black-knobbed sawback, *Graptemys nigrinoda deticola* Folkerts and Mount. Master's thesis, Auburn University, Auburn, Alabama. 275 pages.

Moll, D. 1976. Food and feeding strategies of the Ouachita map turtle (*Graptemys pseudogeographica ouachitensis*). American Midland Naturalist 96: 478–482.

Moll, E. O., and **J. M. Legler.** 1971. The life history of a neotropical slider turtle, *Pseudemys scripta* (Schoepff) in Panama. Natural History Museum, Los Angeles County Science Bulletin 11: 1–102.

Pappas, M. J., and **B. J. Brecke.** 1992. Habitat selection of juvenile Blanding's turtles, *Emydoidea blandingii*. Journal of Herpetology 26: 233–234.

Parmenter, R. R. 1981. Digestive turnover rates in freshwater turtles: the influence of temperature and body size. Comparative Biochemistry and Physiology 70A: 235–238.

Parmenter, R. R., and **H. W. Avery.** 1990. The feeding ecology of the slider turtle. Pages 257–266 *in* Life History and Ecology of the Slider Turtle. *Edited by* J. W. Gibbons. Smithsonian Institution Press, Washington, D. C.

Plummer, M. V. 1977. Activity, habitat, and population structure in the turtle, *Trionyx muticus*. Copeia 1977: 431–440.

SAS Institute. 1988. SAS/Stat User's Guide. SAS Institute Incorporated, Cary, North Carolina.

Sexton, O. J. 1959. Spatial and temporal movements of a population of the painted turtle, *Chrysemys picta marginata* (Agassiz). Ecological Monographs 29: 113–140.

Thornhill, G. M. 1982. Comparative reproduction of the turtle, *Chrysemys scripta elegans*, in heated and natural lakes. Journal of Herpetology 16: 347–353.

Tinkle, D. W., J. D. Congdon, and **P. C. Rosen.** 1981. Nesting frequency and success: implications for the demography of painted turtles. Ecology 62: 1426–1432.

Werner, E. E., and **D. J. Hall.** 1988. Ontogenetic habitat shifts in bluegill: the foraging rate-predation risk trade-off. Ecology 69: 1352–1366.

Wilbur, H. M. 1975. The evolutionary and mathematical demography of the turtle *Chrysemys picta*. Ecology 56: 64–77.

Williamson, L. U., J. R. Spotila, and **E. A. Standora.** 1989. Growth, selected temperature and CTM of young snapping turtles, *Chelydra serpentina*. Journal of Thermal Biology 14: 33–39.

Received 29 May 1991
Accepted 15 April 1992

Notes

A Method for Decreasing Trap Mortality of *Sorex*

JOHN A. YUNGER[1], RICHARD BREWER, and RHONDA SNOOK[2]

Department of Biological Sciences, Western Michigan University, Kalamazoo, Michigan 49008
[1]Present address: Department of Biological Sciences, Northern Illinois University, DeKalb, Illinois 60115
[2]Department of Zoology, Arizona State University, Tempe, Arizona 85287

Yunger, John A., Richard Brewer, and Rhonda Snook. 1992. A method for decreasing trap mortality of *Sorex*. Canadian Field-Naturalist 106(2): 249–251.

Due to high mortality rates, live trapping *Sorex* spp. is difficult. In an attempt to reduce mortality we used food supplements in pitfall traps. Red worms (*Eisenia foetida*) did not significantly reduce trap mortality of Masked Shrews (*Sorex cinereus)*; however, about 7 g of whitefish per pitfall did significantly reduce trap mortality. This method may be useful for studies requiring the live capture of *Sorex* spp. and when trapping in situations where species of shrews having special concern may be encountered.

Key Words: Shrew, *Sorex* spp., mortality, trap, bait, fish, pitfall.

Relatively little is known about the home range and spatial patterns of shrews as compared to other small mammals. Numerous papers attest to the trappability of *Sorex*, (e.g., Anderson 1981; Haveman 1973; Moore 1949; Quimby 1943; Verme and Ozoga 1981) though few studies have been directed at live capture. This may be attributed to high mortality from live trapping, particularly of the smaller species in the genus *Sorex* (Baker 1983). The primary factor believed to contribute to the excessive mortality is high metabolic rate (Pearson 1947), ultimately leading to starvation.

We are aware of seven studies that attempted live capture of *Sorex* (Anderson 1977; Buckner 1966; Crowcroft 1951*a*; Getz 1961; Manville 1949; Pruitt 1959; Sarrazin and Bider 1973). Of these seven, three, Buckner (1966), Getz (1961), and Manville (1949), provide explicit information on mortality rates.

Getz (1961), using Burt live traps (Burt 1940) baited with rolled oats, captured 74 *S. cinereus*. The traps were checked twice daily, once at 0800 h to 1100 h and again from 1600 h to 1800 h. Of the 74 individuals captured, only nine (12%) survived. Manville (1949) used a variety of small box traps ("36" traps, described by Blair [1941], Sherman traps, Burt traps, and Fisher traps) baited with rolled oats and sunflower seeds. Traps were checked in the morning and afternoon and two or three times in-between. Of the 67 *S. cinereus* captured only two individuals (3%) survived.

The large number of recaptures for *S. arcticus* and *S. cinereus* reported in Buckner (1966) suggests he may have had relatively low mortality of these species, though mortality or survival cannot be determined from his paper. Sarrazin and Bider (1973) reported that they captured 622 *S. cinereus*, 504 of which were marked for recapture. The implication is that the mortality rate was 19%. Such low mortality may be due to the fact that Sarrazin and Bider checked their traps (pitfalls) every hour. This approach presents obvious logistic problems in addition to continuous disturbance of the study site.

As part of a larger study examining small mammal populations we live trapped *S. cinereus* in a southwest Michigan sphagnum-leatherleaf bog. The study site is located at the northern end of Portage Bog (T2S, R11W, Sec 28, NW $^1/_4$) Kalamazoo County, Michigan. A detailed description of the vegetation of Portage Bog was given by Brewer (1966).

A 110 by 110 m trapping grid with 10 m intervals was constructed. A pitfall trap was placed at each grid intersection, resulting in 144 traps. The pitfalls were plastic buckets 10 cm wide and 20 cm deep such as are used for bulk quantities of food. They are ideal for trapping because they are available at low cost and in large quantities from most university food services, can be nested, and are lightweight aiding in transport, and have snap-on lids that allow closure between trapping periods. The pitfalls were placed so the opening of the bucket was flush with ground level. Pitfalls were used because they have been shown to have significantly greater success at capturing shrews than other types of traps (MacLeod and Lethiecq 1963; Prince 1941; Pucek 1969).

Trapping was conducted from 7 May 1988 to 27 September 1988. Traps, set for four consecutive nights every two weeks, were checked between 0700 h to 1000 h and 1500 h to 1800 h. To avoid rain and cold night temperatures, the pitfalls were kept closed during some nights in the spring. Minimum temperatures during pitfall trapping, as recorded by a minimum/maximum thermometer, ranged from 19°C to 24°C.

In an initial attempt to reduce mortality from starvation, red worms (*Eisenia foetida*) were placed in the pitfalls on two trap nights (8, 9 June). Worms were selected over other potential food types because they are a natural constituent of *Sorex* spp. diets (Hamilton 1930; Hamilton 1941; Ryan 1986; Whitaker and Mumford 1972; Whitaker and Schmeltz 1973), commercially available in large quantities, and relatively inexpensive. *Sorex cinereus* is known to consume at least its own weight (3.5 g to 5.5 g; Baker 1983) in food daily (Blossom 1932). Based on this consumption rate, four worms (~7 g) were placed in each pitfall.

Twelve *S. cinereus* were captured during the two nights worms were used. Only two (16.7%) survived (Table 1; minimum low temp = 19°C). Due to the high mortality we sought a more satisfactory food supplement.

Pearson (1950) and Rudd (1953), using a mixture of $^2/_3$ brains and $^1/_3$ dog food, maintained captive colonies of three different *Sorex* spp. by feeding them every 24 h. Crowcroft (1951*b*) fed captive Common Shrews (*S. aranus*) and Pygmy Shrews (*S. minutus*) fish, which "was eagerly devoured." Consequently, due to its commercial availability, seven grams of whitefish were placed in the pitfalls on a total of 10 nights. Three of these nights are not included in the analysis because of disturbance by raccoons (*Procyon lotor*). During the remaining seven nights (26, 27 June, 12, 26, 29 July, 29 August, and 1 September) a total of 40 *S. cinereus* were captured. Of these, 31 (77.5%) survived (Table 1; min low temp = 21°C). This survival rate far exceeds the survival rate of previous studies attempting live capture of *Sorex*. Shrews captured in the pitfall traps were observed for 15 to 30 min before handling and releasing. All individuals readily consumed the fish.

To eliminate any effects of temperature, fat deposits, and other possible variables, the effects of supplemented food was examined further by a field experiment conducted using the same grid. Seven grams of fish were placed in alternate traps, creating a "checkerboard" pattern (fish supplemented n = 72, unsupplemented n = 72). The pitfalls were opened between 1700 h to 1800 h and checked the following morning between 0800 h to 1000 h. Trapping was conducted from 29 September to 2 October and from 12 to 15 October. During trapping temperatures reached a low of 7°C (mean low temp = 10°C).

TABLE 1. Number of captures (n = 52) and survival rate of *Sorex cinereus* with worms and fish in pitfall traps.

Survivorship	Worms	Fish	Total
Alive	2	31	33
Dead	10	9	19
Total	12	40	52

TABLE 2. Number of captures (n = 14) and survival rate of *Sorex cinereus* in fish-supplemented and unsupplemented pitfall traps.

Survivorship	Fish supplemented	Unsupplemented	Total
Alive	7	1	8
Dead	1	5	6
Total	8	6	14

Of six individuals captured in the unsupplemented traps one (16.7%) survived. In the fish-supplemented traps eight individuals were captured and seven (87.5%) survived (Table 2). This is a significant reduction in mortality even when the conservative Yates correction for continuity is applied (df = 1, $\chi^2 = 4.430$, $p < 0.035$).

All food-supplemented pitfalls that captured shrews still had some fish remaining in them when checked; thus it appears 7 g of fish is enough to sustain one individual overnight. Also, shrews were observed eating fish that had remained in the traps for four days (29 August to 1 September trapping period).

Though a still greater decrease in mortality is desirable, the use of fish in pitfall traps provides adequate survivorship for most studies requiring the live capture of *Sorex*. The method should also be employed when trapping in situations where species of shrews having special concern status may be encountered (i.e. so individuals of threatened or endangered species or members of peripheral populations are not killed).

Acknowledgments

We thank Bill Caire for critically reviewing an earlier draft of the manuscript and Mark Betz and Paul Diezpak for assistance in the field.

Literature Cited

Anderson, T. J. 1977. Population biology of the masked shrew, *Sorex cinereus*, in hardwood forest areas of the McCormick Experimental Forest, Marquette County, Michigan. Unpublished masters thesis, Northern Michigan University, Marquette. viii + 75 pages.

Anderson, T. J. 1981. Reproductive status of an upland

population of masked shrews. Ohio Journal of Science 81: 161–164.

Baker, R. H. 1983. Michigan mammals. Michigan State University Press, Detroit. 642 pages.

Blair, W. F. 1941. A simple and effective live trap for mammals. Journal of Wildlife Management 5: 191–193.

Blossom, P. M. 1932. A pair of long-tailed shrews (*Sorex cinereus cinereus*) in captivity. Journal of Mammalogy 13: 136–143.

Brewer, Richard. 1966. Vegetation of two bogs in southwest Michigan. Michigan Botanist 5: 36–46.

Buckner, C. H. 1966. Populations and ecological relationships of shrews in tamarack bogs of southeastern Manitoba. Journal of Mammalogy 47: 181–194.

Burt, W. H. 1940. Territorial behavior and populations of some small mammals in southern Michigan. University of Michigan, Miscellaneous Publications of the Museum of Zoology Number 45. 58 pages.

Crowcroft, P. 1951*a*. Keeping British shrews in captivity. Journal of Mammalogy 33: 354–355.

Crowcroft, P. 1951*b*. Live-trapping British shrews. Journal of Mammalogy 33: 355–356.

Getz, L. L. 1961. Factors influencing the local distribution of shrews. American Midland Naturalist 65: 67–68.

Hamilton, W. J., Jr. 1930. The food of the Soricidae. Journal of Mammalogy 11: 26–39.

Hamilton, W. J., Jr. 1941. Food of small mammals. Journal of Mammalogy 22: 250–263.

Haveman, J. R. 1973. A study of population densities, habitats and foods of four sympatric species of shrews. Unpublished masters thesis, Northern Michigan University. vii + 70 pages.

MacLeod, C. F., and **J. L. Lethiecq.** 1963. A comparison of two trapping procedures for *Sorex cinereus*. Journal of Mammalogy 44: 277–287.

Manville, R. H. 1949. A study of small mammal populations in northern Michigan. University of Michigan, Miscellaneous Publications of the Museum of Zoology, Number 73. 83 pages.

Moore, J. C. 1949. Notes of the shrew, *Sorex cinereus*, in the southern Appalachians. Ecology 30: 234–237.

Pearson, O. P. 1947. The rate of metabolism of some small mammals. Ecology 28: 127–145.

Pearson, O. P. 1950. Keeping shrews in captivity. Journal of Mammalogy 31: 351–352.

Prince, L. A. 1941. Water traps capture pigmy shrew (*Microsorex hoyi*) in abundance. Canadian Field-Naturalist 55: 72.

Pruitt, W. O. Jr. 1959. Microclimates and local distribution of small mammals on the George reserve, Michigan. University of Michigan, Miscellaneous Publications of the Museum of Zoology, Number 109. 27 pages.

Pucek, Z. 1969. Trap response and estimation of numbers of shrews in removal catches. Acta Theriologica 14: 403–426.

Quimby, D. 1943. Notes on the long-tailed shrews in Minnesota. Journal of Mammalogy 24: 261–262.

Rudd, R. L. 1953. Notes on the maintenance and behavior of shrews in captivity. Journal of Mammalogy 34: 118–120.

Ryan, J. M. 1986. Dietary overlap in sympatric populations of pygmy shrews, *Sorex hoyi*, and masked shrews, *Sorex cinereus*, in Michigan. Canadian Field-Naturalist 100: 225–228.

Sarrazin, J. P., and **J. R. Bider.** 1973. Activity, a neglected parameter in population estimate — the development of a new technique. Journal of Mammalogy 54: 369–382.

Verme, L. J., and **J. J. Ozoga.** 1981. Changes in small mammal populations following clear-cutting in upper Michigan conifer swamps. Canadian Field-Naturalist 95: 253–256.

Whitaker, J. O., and **R. E. Mumford.** 1972. Food and ectoparasites of Indiana shrews. Journal of Mammalogy 53: 329–335.

Whitaker, J. O., and **L. L. Schmeltz.** 1973. Food and external parasites of *Sorex palustris* and food of *Sorex cinereus* from St. Louis County, Minnesota. Journal of Mammalogy 54: 283–285.

Received 19 November 1990
Accepted 3 March 1992

Bat Hibernacula on Lake Superior's North Shore, Minnesota

BRUCE KNOWLES

308 East Orange Street, Duluth, Minnesota 55811

Knowles, Bruce. 1992. Bat hibernacula on Lake Superior's North Shore, Minnesota. Canadian Field-Naturalist 106(2):252–254.

In January 1990, 308 individual bats of four species (*Myotis lucifugus, M. septentrionalis, Eptesicus fuscus, Pipistrellus subflavus*) were found hibernating in two caves along Lake Superior's North Shore in Minnesota. These are the first known natural hibernacula in northern Minnesota, and this is a northerly range extension for *P. subflavus*. Local rock structure suggests the possibility of a significantly larger overwintering population than observed to date.

Key Words: Vespertilionidae, Little Brown Bat, *Myotis lucifugus*, Northern Myotis, *Myotis septentrionalis*, Big Brown Bat, *Eptesicus fuscus*, Eastern Pipistrelle, *Pipistrellus subflavus*, hibernation, Minnesota.

Of the four bat species known to hibernate in Minnesota, only Big Brown Bats (*Eptesicus fuscus*) have been regularly found wintering above-ground in human structures. Little Brown Bats (*Myotis lucifugus*), Northern Myotis (*Myotis septentrionalis*), and Eastern Pipistrelles (*Pipistrellus subflavus*) normally winter below-ground in caves, mines, or storm sewers (Hitchcock 1949; Goehring 1954; Nordquist and Birney 1985). Northern Myotis and Eastern Pipistrelles are classified in Minnesota as species of State Special Concern (Nordquist and Birney 1988). Since hibernating bats require high humidity, minimal disturbance and low, stable, above freezing temperatures, natural hibernacula are rare (Davis 1970). In Minnesota, suitable natural locations are restricted largely to sedimentary-strata solution caves in the state's southeastern quarter (Ojakangas and Matsch 1982).

Palisade Head (47°19'N; 91°12'W) is a large rhyolite mass fronting 1 km along Lake Superior, 130 km northeast of Duluth, Minnesota (Miller et al. 1989). The 30-60 m vertical face is maintained by columnar joints and the basal talus slope leads directly into water. Two caves have been found here, both apparently the result of wave erosion on former shorelines (John C. Green, Geology Department, University of Minnesota, Duluth, personal communication). Collapsed rock now obscures the openings to each cave; entry is through narrow, vertical crawl spaces. On 13 January 1990 assistants and I found 208 torpid bats, 37 in Hole-in-the-Head and 271 in Gnomen Cave.

Although not on the Minnesota Cave List maintained by the Minnesota Speleological Survey, Hole-in-the-Head, near Palisade Head's southwestern end, has been known for several years to climbers who use it as a refuge during adverse summer weather (David Pagel, personal communication). This cave is irregularly shaped, with two rooms. The outer room measures approximately 10 m long, 4 m wide, and 2 m high. Temperatures taken with a Bacharach sling psychrometer indicated -1°C wet bulb, 0°C dry bulb. In this room 9 Little Brown Bats, 20 Northern Myotis and 8 Big Brown Bats were found torpid. The Little Brown Bats hung solo except for a single cluster of three and for one individual clustered with seven Northern Myotis. The Northern Myotis were clustered in pairs and trios except for one solo bat and the cluster of eight mentioned above. The Big Brown Bats hung as two solos, one pair, and one cluster of four.

The inner room of Hole-in-the-Head, connected to the outer room by a short crawl space, is roughly a vertical cylinder 3 m across and 5 m high. With two broad cracks accessing the surface, it was drafty, colder, and unoccupied by bats.

Unknown until September 1989, Gnomen Cave is a single room, 24 m long, 10 m wide, and averaging 2 m high near Palisade Head's northeastern end. Temperature readings were 0°C wet bulb, 1°C dry bulb. We observed 27 Little Brown Bats, 8 Big Brown Bats, 1 Northern Myotis, and 1 Eastern Pipistrelle hanging singly, in pairs, or trios on the walls and low ceiling. Consistent with a reported preference for high-ceiling cluster sites (Brack and Twente 1985) 234 additional Myotis not identified to species occupied the main ceiling crevice, which reaches 4 m above the cave floor. These bats occurred in various sized clusters.

The single Eastern Pipistrelle represents the first record of this species in northern Minnesota. The 7.5-g female was found hanging solo in the cave's crawlspace, consistent with previous observations of site selection (Pruszko and Bowles 1986; Rabinowitz 1981). Since we banded this individual, subsequent observation can check Hassell's (1967) finding that Eastern Pipistrelles display site fidelity to hibernacula. Palisade Head is located 320 km north-northeast of Leslie Cave, the previously reported northern extreme for confirmed Eastern Pipistrelle hibernation (Nordquist and Birney 1985), and 128 km northwest of Hurley, Wisconsin, where Greeley and Beer (1949) captured a single fattened male active at an abandoned mine entrance in early September, providing suspicion that it hibernated there.

While respecting the need of hibernating bats for minimal disturbance, three subsequent visits were intended to determine the bats' shifting seasonal cave use and approximate timing of first autumn occupation. On 30 June 1990 no bats were found occupying either Gnomen Cave or Hole-in-the-Head at midday. Both caves had wet, actively dripping ceilings, presenting unattractive environments for daytime roosting. On 9 September 1990 Gnomen Cave was inspected at midday, but no bats were found. On 23 September 1990 Gnomen Cave was occupied at midday by 93 torpid bats, a mixture of Little Brown Bats and Northern Myotis. One additional Northern Myotis was found semi-torpid 2 m from the cave entrance. All other bats were hanging on the interior wall and ceiling either solo or in clusters of 2–6. The main ceiling crevice was still wet and unoccupied. Cave temperature was measured at 8°C. Protection of these hibernacula might be appropriate due to Palisade Head's recreational use by climbers and the bats' vulnerability to disturbance.

Cave bats are common summer residents in northern Minnesota. These bats can be expected to use nearby hibernacula if available, thus avoiding unnecessary dangers and energy costs of migration. This has proven true in northern Minnesota and northwestern Ontario where highway tunnels and abandoned mine shafts have been colonized by populations of overwintering bats (Fenton 1969; Nagorsen 1980; Nordquist and Birney 1985) and near Thunder Bay, Ontario, where a winter bat population of 1500 has been reported at the single documented natural hibernaculum (Allin 1942).

Surface geology in this region is not conducive to cave formation and very few caves have been found (Alexander 1980; Ojakangas and Matsch 1982). The Palisade Head area presents good possibilities for additional hibernation sites and should be investigated. A vertical fracture system with ramifying joints provides deep, narrow crevices in which thermal stability can be expected. Since these four bat species can easily negotiate 1 cm crevices, such honeycombing suggests the possibility of a much larger overwintering population than has been detected in the two caves accessible to humans.

Hitchcock (1965) reported these same species hibernating in small cracks within natural caves and speculated that such cracks function as refuges in which torpid bats go undetected by human observers. Hassell (1967) reported that during the colder part of winter Little Brown Bats retreated into crevices, making their numbers impossible to estimate. There is evidence that bats have attempted to hibernate in this local joint system, although that evidence is in the failure of certain individuals to survive the full winter. In mid-March 1989 Mike McCall discovered a Big Brown Bat at Palisade Head's eastern end, and a Little Brown Bat 2 km northeast at Crystal Bay. Both bats (specimens available at Wolf Ridge Environmental Learning Center, Finland, Minnesota) were found dead on recently formed lake ice directly below vertical fractures in rhyolitic Lake Superior sea caves. In late December 1989 Joyce Klees of Tofte, Minnesota, found but did not collect a dead bat at the base of Pigeon Falls (48°00'N; 89°36'W), located 3 km upstream from Lake Superior along the Minnesota-Ontario border. The diabase dike causing these falls (Green 1989) also exhibits crevice-forming fractures.

Acknowledgments

Roger Harkess discovered and reported Gnomen Cave; David Pagel assisted the first descent. Gerda Nordquist, Minnesota Department of Natural Resources, contributed field expertise and galloping enthusiasm. At the University of Minnesota, Duluth, Don Christian made valuable editorial suggestions and John Green offered field expertise plus critical comments. Nancy Hylden and Catherine Long reviewed the manuscript. I thank these people for their help and interest.

Literature Cited

Alexander, E. C., Jr. *Editor.* 1980. An introduction to the caves of Minnesota, Iowa, and Wisconsin. National Speleological Society convention guidebook (21). Lakewood Community College, White Bear Lake, Minnesota.

Allin, A. E. 1942. Bats hibernating in the district of Thunder Bay, Ontario. Canadian Field-Naturalist 56: 90–91.

Brack, V., Jr., and **J. W. Twente.** 1985. The duration of the period of hibernation of three species of vespertilionid bats. Canadian Journal of Zoology 63(3): 2952–2954.

Davis, W. H. 1970. Hibernation: ecology and physiological ecology. Pages 266-300 *in* Biology of Bats. *Edited by* W. A. Wimsatt. Academic Press, New York. 406 pages.

Fenton, M. B. 1969. Summer activity of *Myotis lucifugus* (Chiroptera: Vespertilionidae) at hibernacula in Ontario and Quebec. Canadian Journal of Zoology 47(1): 597–602.

Goehring, H. H. 1953. *Pipistrellus subflavus obscurus, Myotis keenii,* and *Eptesicus fuscus fuscus* hibernating in a storm sewer in central Minnesota. Journal of Mammalogy 35(3): 434–435.

Greeley F., and **J. R. Beer.** 1949. The Pipistrel (*Pipistrellus subflavus*) in northern Wisconsin. Journal of Mammalogy 30: 198.

Green, J. C. 1989. Evaluation of the Pigeon River high falls area, Cook County, Minnesota, as a potential National Natural Landmark. Prepared for United States National Park Service, Omaha, Nebraska.

Hassell, M. D. 1967. Intra-cave activity of four species of bats hibernating in Kentucky. Ph.D. dissertation. University of Kentucky, Lexington.

Hitchcock, H. B. 1949. Hibernation of bats in southeastern Ontario and adjacent Quebec. Canadian Field-Naturalist 63: 47–59.

Hitchcock, H. B. 1965. Twenty-three years of bat banding in Ontario and Quebec. Canadian Field-Naturalist 79: 4–14.

Miller, J. D., Jr., J. C. Green, and **T. J. Boerboom.** 1989. Geologic map of the Illgen City Quadrangle, Lake County, Minnesota. Minnesota Geological Survey, Miscellaneous Map M-66, St. Paul.

Nagorsen, D. W. 1980. Records of hibernating Big Brown Bats (*Eptesicus fuscus*) and Little Brown Bats (*Myotis lucifugus*) in northwestern Ontario. Canadian Field-Naturalist 94(1): 83-85.

Nordquist, G. E., and **E. C. Birney**. 1985. Distribution and status of bats in Minnesota. Nongame Wildlife Program, Minnesota Department of Natural Resources, St. Paul.

Nordquist, G. E, and **E. C. Birney.** 1988. Mammals. Pages 293-322 *in* Minnesota's endangered flora and fauna. *Edited by* B. Coffin and L. Pfannmuller. University of Minnesota Press. 474 pages.

Ojakangas, R. W., and **C. L. Matsch.** 1982. Minnesota's geology. University of Minnesota, Duluth.

Pruszko, R., and **J. B. Bowles.** 1986. Survey of some eastern Iowa caves for wintering bats. Proceedings of the Iowa Academy of Science 93(2): 41-43.

Rabinowitz, A. 1981. Thermal preference of the Eastern Pipistrelle bat (*Pipistrellus subflavus*) during hibernation. Journal of the Tennessee Academy of Science 56(4): 113-114.

Received 21 December 1990
Accepted 19 August 1992

Breeding Gadwalls, *Anas strepera*, near Yellowknife, Northwest Territories

MICHAEL A. FOURNIER[1], DAVID L. TRAUGER[2], JAMES E. HINES[1], and DAVID G. KAY[1]

[1]Canadian Wildlife Service, P.O. Box 637, Yellowknife, Northwest Territories X1A 2N5
[2]United States Fish and Wildlife Service, Patuxent Wildlife Research Centre, Laurel, Maryland 20708

Fournier, Michael A., David L. Trauger, James E. Hines, and David G. Kay. 1992. Breeding Gadwalls, *Anas strepera*, near Yellowknife, Northwest Territories. Canadian Field-Naturalist 106(2): 254–256.

Evidence of Gadwalls breeding near Yellowknife, Northwest Territories was observed in 1966, 1989, and 1990. These observations appear to be the most northerly breeding records for this species in North America. Recent observations of Gadwalls in the Yellowknife area may be explained by one or more of the following; an increased number of observers, drought displacement, population increase and range expansion. Numerous sightings of Gadwalls have been reported for the western Northwest Territories, suggesting that the breeding range in North America may extend north to latitudes similar to those reported for the Palearctic.

Key Words: Gadwall, *Anas strepera*, breeding waterfowl, Northwest Territories, boreal forest.

In western North America, the Gadwall, *Anas strepera*, breeds primarily from southern British Columbia, northern Alberta, central Saskatchewan, and central-western Manitoba south to approximately 40°N latitude (Bellrose 1976). Primary breeding habitat is mixed grasslands; parklands are of secondary importance and only small numbers of Gadwalls nest in the boreal forest (Bellrose 1976). The centre of the breeding distribution, therefore, occurs well south of Yellowknife, Northwest Territories (62°27'N, 114°22'W) where breeding Gadwalls were observed in 1966, 1989, and 1990.

Palmer (1976) stated that the Gadwall's breeding range has expanded northward in recent decades. Northerly extralimital breeding records for the Gadwall in North America include several areas in Alaska — the Copper River Delta (60°55'N, 144°85'W), Juneau (58°20'N, 134°20'W) and the Alaskan Peninsula [approximately 57°32'N, 157°25'W] (Kessel and Gibson 1978). Small local breeding populations occur at Hay-Zama Lakes in northwestern Alberta [58°45'N, 119°00'W] (Salt and Salt 1976), about 490 km southwest of Yellowknife, and the delta of the Athabasca River [58°40'N, 111°10'W] (Nero 1963), about 468 km southeast of Yellowknife. A "hypothetical" breeding record exists for Nahanni National Park Reserve, near Virginia Falls, N.W.T. [61°38'N, 125°44'W] (Carbyn and Patriquin 1976).

The Gadwall has been reported in a number of northerly locations in Europe and Asia. It breeds at Lake Myvatn and vicinity, Iceland [65°36'N, 17°00'W] (Cramp 1977) as well as the island of Hailuoto in the Gulf of Bothnia, Finland [65°01'N, 24°45'E] (Pirkola 1983). In the Soviet Union it may breed north of 60°N latitude along the Irtysh River (Dement'ev and Gladkov 1952). In the United Kingdom the Gadwall has been reported breeding as far north as Sanday Island in the Orkneys [59°15'N, 2°30'W] (Sharrock 1977).

TABLE 1. Other observations of Gadwalls in the Northwest Territories*.

Date		Number Observed	Location	Source
2 August	1966	several pairs	Yellowknife Hwy.	H. Kantrud pers. comm.
26 May	1972	1 pair	Fort Simpson 61°52'N, 121°21'W	Salter 1974
16 May	1974	4	Fort Providence 62°21'N, 117°39'W	Salter et al. 1974
16 May	1974	1 pair	Wrigley 63°14'N, 123°28'W	Salter et al. 1974
18 May	1974	1 pair	Fort Providence	Salter et al. 1974
13-24 May	1974	24	Fort Simpson	Salter et al. 1974
19 June-3 July	1985	30 mostly males	Mackenzie River Delta 68°53'N, 136°58'W	Hawkings 1986
29 May	1988	4 pairs, 1 male	Stagg River 73 km NW of Yellowknife	M. Fournier unpubl. data
June	1988	1 pair	Inuvik 68°21'N, 133°43'W	G.B. Cameron pers. comm.
1 June	1989	1 pair	Yellowknife Hwy. 60 km NW	J. Hines unpubl. data
June	1989	1 pair	Tuktoyaktuk 69°27'N, 133°02'W	G.B. Cameron pers. comm.
15 August	1989	1 female	Yellowknife Hwy. 60 km NW	J. Hines unpubl. data
28 May	1990	1 pair	Yellowknife Hwy. 55 km NW	M. Fournier unpubl. data
7 June	1990	1 male	Yellowknife Hwy. 56 km NW	M. Fournier unpubl. data
15 June	1990	1 pair	Yellowknife Hwy. 53 km NW	M. Fournier unpubl. data
5 July	1990	1 female	Yellowknife Hwy. 56 km NW	J. Hines unpubl. data
15 May	1991	1 male	Yellowknife – Niven Lake	J. Sirois pers. comm.

*Small numbers of Gadwalls were also observed (from aircraft) occasionally during the early 1970s and regularly between 1977 and 1987 on United States Fish and Wildlife Service surveys south and west of Great Slave Lake. Estimates based on similar surveys indicate that as many as 1300 Gadwalls may have been present in the Mackenzie Delta in 1977, 1979 and 1983 (Hawkings 1987).

Breeding records near Yellowknife, Northwest Territories

On 2 August 1966, DLT sighted a female Gadwall with a 3–4 week old duckling (Class IIa, Gollop and Marshall 1954) on a shallow pond 48 km northwest of Yellowknife. On the basis of this observation, the Gadwall was designated as a "rare" breeder in the Yellowknife area (Bromley and Trauger *no date*). This note is the first published account of that breeding record.

On 7 July 1989, while searching for duck nests on a rocky island in the North Arm of Great Slave Lake (62°31'N, 115°11'W), MAF, JEH, and DKG flushed a female Gadwall from a nest containing nine eggs. Later that day, another female Gadwall was observed on an island about 4 km distant (62°32'N, 115°16'W). Although the second Gadwall behaved like a nesting female, flushing at a distance of less than 5 m, no Gadwall nest was found during a thorough search of the sparsely vegetated island. We did, however, find four Gadwall eggs in the nest of a Red-breasted Merganser (*Mergus serrator*) (which also contained nine merganser eggs).

On 21 June 1990, a Gadwall nest containing seven eggs was discovered (MAF and DGK) on an island in the North Arm of Great Slave Lake (62°32'N, 115°16'W). This island is located approximately 4.8 km from the Gadwall nest-site observed in 1989 and approximately 50 metres (on a different island) from the merganser nest parasitized by a Gadwall (also observed in 1989).

Other observations of Gadwalls in the Northwest Territories

Although we believe that the above observations represent the most northerly breeding records for Gadwalls in North America, it is possible that the species breeds elsewhere in the western Northwest Territories. We have reviewed accounts (published and unpublished) of Gadwall observations in the region and summarized them in Table 1. These observations of Gadwalls throughout the Mackenzie River Valley during the breeding season and our observations of breeding near Yellowknife suggest that Gadwalls breed at northern latitudes in North America similar to those reported for the Palearctic.

Discussion

There are three plausible explanations for the recent breeding records and observations of Gadwalls near Yellowknife. Firstly, they may simply reflect an increase in the number of observers. There have been few avifaunal studies undertaken on the North Arm of Great Slave Lake where breeding Gadwalls were observed in 1989 and 1990. However, Gadwalls were not observed during waterfowl studies along the Yellowknife Highway between 1985 and 1987 (inclusive) but have been recorded in this area in each subsequent year.

The second possible explanation is that dry conditions in prairie breeding areas may have resulted in some Gadwalls moving north into the boreal forest near Yellowknife, where more stable water conditions prevail. At least one measure of the condition

of prairie breeding habitats, the number of ponds observed in May, indicated a substantial reduction in habitat quality in the years 1988-1990 (Anonymous 1988, 1989, 1990).

The third possible explanation is that our observations are indicative of an increase in population size and subsequent range expansion. Henny and Holgersen (1974) documented the increase in numbers and expansion of the breeding range of the Gadwall in eastern North America. Dickson (1989) reported a 40 percent increase in the continental population of Gadwalls over the period 1955-1989. A population increase of 498 percent was observed in boreal regions over this same period with an increase of 158 percent between 1985 and 1989.

In all likelihood a combination of these factors may best explain our observations.

Acknowledgments

The authors would like to thank K. McCormick, R. Ferguson, M. C. Perry, C. Robbins, and two anonymous referees for reviewing the manuscript, M. Gosselin of the Canadian National Museum of Natural Science (now Canadian Museum of Nature) for providing information concerning breeding records, and A. Soneine for providing Finnish translation.

Literature Cited

Anonymous. 1988. 1988 Status of waterfowl and fall flight forecast. U.S. Fish and Wildlife Service and Canadian Wildlife Service. 37 pages.

Anonymous. 1989. 1989 Status of waterfowl and fall flight forecast. U.S. Fish and Wildlife Service and Canadian Wildlife Service. 39 pages.

Anonymous. 1990. 1990 Status of waterfowl and fall flight forecast. U.S. Fish and Wildlife Service and Canadian Wildlife Service. 43 pages.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Wildlife Management Institute. Washington. 540 pages.

Bromley, R. G., and **D. L. Trauger.** *no date* [1981?]. Birds of Yellowknife — a regional checklist. 12 pages.

Carbyn, L. N., and **D. Patriquin.** 1976. Description of the wildlife component for impact assessment of three potential campsite locations in Nahanni National Park, N.W.T. Canadian Wildlife Service, Edmonton. 187 pages.

Cramp, S., *Editor.* 1977. Handbook of the Birds of Europe, the Middle East and North Africa. The birds of the Western Palearctic. Volume 1. Ostrich to Ducks. Oxford University Press. London. 722 pages.

Dement'ev, G. P., and **N. A. Gladkov.** *Editors.* 1952. Birds of the Soviet Union. Volume IV. Israel Program for Scientific Translation. Jerusalem. 683 pages.

Dickson, K. M. 1989. Trends in sizes of breeding duck populations in western Canada, 1955-89. Progress Note No. 186. Canadian Wildlife Service, Ottawa. 9 pages.

Gollop, J. B., and **W. H. Marshall.** 1954. A guide for aging duck broods in the field. Mississippi Flyway Council Technical Section. 14 pages.

Hawkings, J. 1986. Breeding bird survey of the Whitefish Station area, Mackenzie Delta, 1985. Technical Report Series No. 4. Canadian Wildlife Service, Pacific and Yukon Region. British Columbia. 22 pages.

Hawkings, J. 1987. Population status of migratory waterbirds on the Yukon coastal plain and adjacent Mackenzie Delta. Technical Report Series No. 28. Canadian Wildlife Service, Pacific and Yukon Region. British Columbia. 65 pages.

Henney, C. J., and **N. E. Holgersen.** 1974. Range expansion and population increase of the Gadwall in eastern North America. Wildfowl 25: 95–101.

Kessel, B., and **D. G. Gibson.** 1978. Status and Distribution of Alaska Birds. Studies in Avian Biology Number 1. Cooper Ornithological Society, University of California, Los Angeles. 100 pages.

Nero, R. W. 1963. Birds of the Lake Athabasca region, Saskatchewan. Special Publication No. 5. Saskatchewan Natural History Society. Regina. 143 pages.

Palmer, R. S. 1976. Handbook of North American Birds. Volume 2. Waterfowl (Part 1). Yale University Press. London. 521 pages.

Pirkola, M. K. 1983. Harmaasorsa *Anas strepera*. Pages 44–45 *in* Suomen Lintuatlas. *Edited by* E. Kellomaki. Suomen atlastoimikunta. Helsinki, Finland.

Salt, W. R., and **J. R. Salt.** 1976. The birds of Alberta: with their ranges in Saskatchewan and Manitoba. Hurtig Publishers. Edmonton. 498 pages.

Salter, R. 1974. Spring migration of birds in the upper Mackenzie Valley, May 1972. Pages 1–31 *in* Bird migrations on the North Slope and in the Mackenzie Valley regions, 1972. *Edited by* W. W. H. Gunn and J. A. Livingston. Arctic Gas Biological Report Series. Volume Thirteen.

Salter, R., W. J. Richardson, and **C. Holdsworth.** 1974. Spring migration of birds through the Mackenzie Valley, N.W.T. April-May, 1973. Pages 1–168 *in* Ornithological studies in the Mackenzie Valley, 1973. *Edited by* W. W. H. Gunn, W. J. Richardson, R. E. Schweinsburg, and T. D. Wright. Arctic Gas Biological Report Series. Volume Twenty-eight.

Sharrock, J. T. R. 1976. The Atlas of Breeding Birds in Britain and Ireland. T. & A. D. Poyser Ltd. Hertfordshire, England. 479 pages.

Received 17 January 1991
Accepted 4 March 1992

Additional Mixed-age Brown Bear, *Ursus arctos*, Associations in Alaska

FREDERICK C. DEAN[1], RICK MCINTYRE[2], and RICHARD A. SELLERS[3]

[1]Department of Biology and Wildlife, University of Alaska-Fairbanks, Fairbanks, Alaska 99775-1780
[2]Cottonwood Ranger Station, Chiriaco Summit, California 92201
[3]Alaska Department of Fish and Game, P.O. Box 37, King Salmon, Alaska 99613-0037

Dean, Frederick C., Rick McIntyre, and Richard A. Sellers. 1992. Additional mixed-age Brown Bear, *Ursus arctos*, associations in Alaska. Canadian Field-Naturalist 106(2): 257–259.

An unusual and extended association of an adult female Brown Bear, a cub-of-the-year, and a female probably 3.5 yr was observed several times throughout the summer of 1986 in Denali National Park, Alaska. The adult appeared to nurse both younger animals. Both older animals exhibited uncharacteristic behavior toward the cub; the presumed mother was relatively disinterested, and the juvenile approached "helping." An adult female with two cubs and two probable yearlings was seen twice in July 1991 on the Alaska Peninsula.

Key Words: Brown Bear, *Ursus arctos*, behavior, helping, Denali National Park, Alaska Peninsula, Alaska.

During the summers of 1986 and 1991 unusual associations of Brown Bears (*Ursus arctos*) were observed in Denali National Park by Dean and McIntyre and on the Alaska Peninsula by Sellers.

The bears in Denali were seen repeatedly between mid-June and mid-September in the Toklat River valley (63°30'N, 150°02'W). The group consisted of an adult female, a cub-of-the-year (hereafter "cub" refers *only* to first year young), and an additional individual estimated at 2.5 or 3.5 years (hereafter, "juvenile"). Figure 1 shows the relative sizes of the three animals and leaves no question about the age of the cub. The authors sighted the group five times from 24 July–mid-September in observations totalling 9 h. The bears all appeared physically normal. Observed urination confirmed the juvenile's sex as female.

We noted several other unusual behaviors in addition to the long-term maintenance of the mixed-age assemblage. Twice both younger bears were simultaneously in nursing position and appeared to suck while the adult female lay on her back; the distance precluded certainty that both got milk. We saw one additional possible nursing event, involving only the juvenile. Additionally, the cub and the juvenile played together several times, biting each other's faces and wrestling in a manner consistent with that of litter mates or a single young with its mother.

During our observations, the cub was commonly 30–75 m from the adult female, whereas most cubs are seldom >30 m from their mothers. However, while relatively distant from the adult, the cub was at times <30 m from the juvenile female. On 16 August, while the older bears were feeding, the cub was >100 m from the adult and >75 m from the juvenile. Another instance of very unusual spatial relationships occurred on 4 September. The group traversed >3 km of tundra, paralleling but 0.8–1.5 km from the park road. Most of the time during this trek, the adult female was 200–400 m ahead of the other two, at times appearing nervous and running; she reportedly had reacted strongly to the sound of a vehicle earlier in the day and may still have been bothered by traffic. The adult occasionally stopped to look back and may have called, but she waited or fed only a few times. The younger animals were left to keep up or to find the way on their own. The cub was frequently 50–100 m behind the juvenile which in turn was >200 m behind the adult female. Twice the cub was 0.4 km or more behind the adult female; visual contact would have been impossible most of the time due to the rough, gullied terrain. At least some of the time, the cub clearly maintained contact by scent. Early in this traverse, the adult female stopped and fought with the juvenile. The action definitely looked and sounded more serious than play; she may have been trying to drive the juvenile off.

In summary, there were consistent but definitely unusual aspects of the behavior of this group association: (a) the adult female's lack of more or less continual and obvious concern for the cub; (b) the frequent separation of the cub and adult female by two to three or more times the usual distance distribution; (c) the association of the cub within a few meters of, and sometimes playing with, the juvenile female; and (d) the adult's nursing of such different-aged young. The juvenile often appeared to be concerned about the location of the cub, checking visually when the smaller bear lagged behind during periods of travel. This behavior distinctly contrasted with (and seemed more typically "maternal" than) that of the adult female.

On 22 July 1991, during the course of an aerial survey, Sellers photographed an adult with two cubs and two probable 1.5–yr young (yearlings) on the Douglas River Flats southeast of McNeil River, approximately 59°00'N, 153°40'W. A photograph clearly shows normal spatial relationships for a

FIGURE 1. Mixed-age Brown Bear association, Denali National Park, 4 September 1986. Adult female in the lead. Enlarged from 35mm negative made with 900 mm lens at about 0.5 km. See text for details.

mother and her young, and the appearance of the presumed yearlings leaves little room for doubt as to their age. While other adult bears were seen in the general area at the time none showed behavior that would link them to either of the two sets of young. On 29 July 1991 during a second flight, the same group was seen within 0.4 km of their previous location. Again, the spatial relationships and behavior were consistent with a mother and her young. While the aircraft circled for a third pass, the adult lay down and rolled onto her back; all four young climbed onto her belly in nursing position.

Extended associations of adult female Brown Bears with young of mixed ages are unusual. Although adoption has been documented or suggested by several workers (Erickson and Miller 1963; Craighead et al. 1969; Wilk et al. 1988), we are aware of only two published reports of extended summertime mixing of ages among Brown Bears (Erickson 1964; Craighead et al. 1969: 464). These involved (1) a single cub with two ≥ 1.5–yr young, and (2) a single cub with an adopted 1.5–yr known orphan respectively; both observations were made where bears concentrated. Bledsoe (1987) provided clear evidence of cub swapping but emphasized that it was uncommon, almost exclusively involved cubs, and required an unusual set of conditions even for bear concentrations such as at McNeil River falls. Schwartz et al. (1987) and Goodrich and Stiver (1989) documented co-denning by unrelated and/or mixed-age young assemblages of Black Bears (*Ursus americanus*).

Several sequences of events can be postulated to explain an association of Brown Bears with young of two ages, but each possibility involves low although unknown probabilities. The cases of adoption reported from the Alaska Peninsula and Yellowstone cited previously were associated with extreme abundance of food and hyper-concentrated bears. Alt (1984) discussed adoption in bears, though focusing on Black Bears, and concluded that the phenomenon was rare under more usual dispersed conditions. Adoption, implying that the adult female established a bond with another female's young, seems very unlikely in the Denali instance. During more than 30 summers at Denali we know of only one case of orphaning, a yearling (1.5 yr, Dean et al. 1986), and have never seen a cub or any other yearling dissociated from its mother for even a few hours. Postulating true adoption of a juvenile animal at least two years older than a current cub greatly exceeds our prior experience and our expectation of probable behavior on the part of either, much less both, the adult female and the juvenile. The Denali case was not a "helping" relationship in the strict sense (Emlen 1984), but the juvenile occasionally functioned in a manner suggesting "babysitting." The adult female clearly had less concern for the cub

than do most bear mothers we have seen, possibly because of the presence of the juvenile. The adult female's apparently weak bond with the cub would be consistent with Tait's (1980) hypothesis that abandonment of single cubs can increase lifetime fitness; however, she had a functional litter size of two.

Assuming that the cub was the adult female's offspring, the most likely relationship between the adult female and the juvenile appears to have been mother-daughter. Our experience suggests that either adoption of a juvenile-aged animal or nursing another's young are highly unlikely where bears are relatively dispersed. We believe that the most conservative explanation of this association is that the juvenile remained loosely attached to the adult female while the latter mated early in 1985 and then rejoined its mother. Constant association post-breeding seems more likely than the juvenile's rejoining its mother after the emergence of the adult and the cub in 1986. One must note that if the juvenile was only 2.5 yr (3rd summer) in 1986 it would have been a yearling when the adult conceived the 1986 cub. In spite of extensive observation of bears in Denali National Park, neither the authors nor Murie (1981) have recorded any cases of females mating the summer their young were yearlings. If mothers of yearlings do mate in that area, it must be very unusual. This strongly suggests that the juvenile of the 1986 mixed-age association was in its fourth summer in 1986. Mother-young associations extending into the 4th summer have been observed in Denali in several cases where group identity was confirmed; one such family was seen nursing several times prior to breaking up during June.

Since the total observation time in Sellers' case was limited, extensive speculation is problematic. Although temporary separation of a mother from older young while she mates has been observed; invoking this explanation would require that the adult had mated while tending cubs which would be extremely unusual.

Annually, for the past 30 or so years there have been very extensive observations of bears in Alaska, both on the ground and from the air. The fact that similar mixed-age groups are not seen more commonly suggests their rarity.

Acknowledgments

We would like to thank R. Terry Bowyer, Department Biology and Wildlife, University of Alaska-Fairbanks; John W. Schoen and Sterling D. Miller, Alaska Department of Fish and Game; and several anonymous reviewers for comments on the manuscript.

Literature Cited

Alt, G. L. 1984. Cub adoption in the black bear. Journal of Mammalogy 65: 511–512.

Craighead, J. J., M. G. Hornocker, and **F. C. Craighead.** 1969. Reproductive biology of young female grizzly bears. Journal of Reproduction and Fertility, Supplement 6 (1969): 447–475.

Bledsoe, T. 1987. Brown bear summer, life among Alaska's giants. E. P. Dutton, New York. 249 pages.

Dean, F. C., L. M. Darling, and **A. G. Lierhaus.** 1986. Observations of intraspecific killing by Brown Bears, *Ursus arctos*. Canadian Field-Naturalist 100: 208–211.

Emlen, S. T. 1984. Cooperative breeding in birds and mammals. Pages 305–339 *in* Behavioural ecology, an evolutionary approach. *Edited by* J. R. Krebs and N. B. Davis. Second edition. Blackwell Scientific Publications, Oxford. 493 pages.

Erickson, A. W. 1964. A mixed-age litter of brown bear cubs. Journal of Mammalogy 45: 312–313.

Erickson, A. W., and **L. H. Miller.** 1963. Cub adoption in the brown bear. Journal of Mammalogy 44: 584–585.

Goodrich, J. M., and **S. J. Stiver.** 1989. Co-occupancy of a den by a pair of Great Basin black bears. Great Basin Naturalist 4: 390–391.

Murie, A. 1981. The grizzlies of Mount McKinley. U.S. Department of the Interior, National Park Service, Scientific Monograph Series Number 14. Washington, D. C. 251 pages.

Schwartz, C. C., S. D. Miller, and **A. W. Franzmann.** 1987. Denning ecology of three black bear populations in Alaska. International Conference of Bear Research and Management 7: 281–291.

Tait, D. E. N. 1980. Abandonment as a reproductive tactic — the example of grizzly bears. American Naturalist 115(6): 800–808.

Wilk, R. J., J. W. Solberg, V. D. Berns, and **R. A. Sellers.** 1988. Brown bear, *Ursus arctos*, with six young. Canadian Field-Naturalist 102: 541–543.

Received 5 December 1990
Accepted 26 March 1992

Westward Range Extension for the Yellow Mountain Saxifrage, *Saxifraga aizoides* (Saxifragaceae): a New Vascular Plant Species to Alaska

CHARLES T. SCHICK

Department of Biological Sciences, University of California, Santa Barbara, California 93106

Schick, Charles T. 1992. Westward range extension for the Yellow Mountain Saxifrage, *Saxifraga aizoides* (Saxifragaceae): a new vascular plant species to Alaska. Canadian Field-Naturalist 106(2): 260–262.

Saxifraga aizoides was collected at Prudhoe Bay, Alaska during the summer of 1989. This is the first record of the species for Alaska, and extends its known range westward by approximately 350 km.

Key Words: Yellow Mountain Saxifrage, *Saxifraga aizoides*, Saxifragaceae, Alaska, amphi-atlantic plant, arctic-alpine plant, range extension.

Yellow Mountain Saxifrage (*Saxifraga aizoides* L.) was collected in July 1989 in the Prudhoe Bay area of Alaska's northeastern arctic coast between the Sagavanirktok and Kuparuk Rivers (70°20'N, 148°30'W). This arctic-alpine plant has an amphi-atlantic and transamerican distribution; its range is disjunct among isolated mountain ranges and arctic regions in Europe and Asia but continuous in North America (Hulten 1968). The species occurs from approximately Novaya Zemlya (60°E) in western Siberia to the northwestern Yukon Territory (140°W) in Canada. This is the first collection from Alaska, and lies some 350 kilometers north and west of the nearest collection site in the Yukon Territory (Figure 1).

S. aizoides as an arctic-alpine plant is part of a common floristic element at Prudhoe Bay where arctic-alpine plants represent 48% of the flora. But *S. aizoides* is also an amphi-atlantic species, part of the smallest floristic element (2%) at Prudhoe Bay (Walker 1985). From this perspective it is a significant addition to the flora.

A single plant was found on 20 July 1989 from which a flowering ramet was collected and deposited with the Herbarium of the University of Alaska Museum (no. V104700, ALA). The plant was found 3.5 km west of the Trans-Alaska oil pipeline along an abandoned "peat road" on the bluffs of the Putuligayuk River. It was growing in moist and partially open peat along the west bank of the river with *Festuca baffinensis*, viviparous *Poa, Saxifraga oppositifolia, Salix arctica, Salix lanata* ssp. *richardsonii, Stellaria laeta,* and *Draba cinerea.* The peat roads at Prudhoe Bay were constructed from tundra (peat) soils in the late 1960's for oil exploration, but quickly abandoned in 1968 when a gravel road system was established. This disturbed and open peat habitat has therefore been open to pioneering plant species for over 20 years.

The Prudhoe Bay area has produced some interesting botanical records since intensive field work commenced there in 1971. In a wide ranging collecting trip Halliday (1977) found three species new to Alaska, two of which (*Pleuropogon sabinei* and *Pedicularis hirsuta*) were collected at Prudhoe Bay. The most recent checklist for the Prudhoe Bay region (Walker 1985) lists some 27 taxa which were unexpected in the area based on the range maps and habitat descriptions given in Hulten (1968), and one species (*Draba subcapitata*) was a first collection for Alaska. This collection of *S. aizoides* represents a fourth new record for Alaska from Prudhoe Bay.

Along Alaska's north coast the Prudhoe Bay region spans a unique portion of coastal plain tundra. Murray (1978) has pointed out that the concentration of large gravel-bedded rivers in the area (draining from the Brooks Range) makes it quite different from the coastal plain tundra to the west (with the exception of the Colville River delta). These rivers provide a corridor for plant migration from the Brooks Range to the south, and the numerous dry river terraces and pingos provide suitable habitat for many arctic-alpine species otherwise restricted from the area by the prevalence of low and wet tundra. Disturbance within the area from oilfield activities may also be playing a role in the establishment of plants; three of the four species recorded as new to the state of Alaska from Prudhoe Bay were collected in sites clearly disturbed by human activities. It remains unclear, however, if the notable botanical records from the region are due to unique habitat, or due to the fact that the area is now well known botanically from intensive study in recent years.

The history of collections of *S. aizoides* from the adjacent Yukon Territory indicates that the species is more common there than previously thought, and in particular its known range has recently been extended north and westward towards Alaska. It was first collected in the Yukon Territory in 1944 (Porsild 1951), and was listed as rare in the Yukon Territory by Douglas et al. (1981). By 1990, however, the species was dropped from the list of rare plants for the region (Argus and Pryer 1990). Then in the same

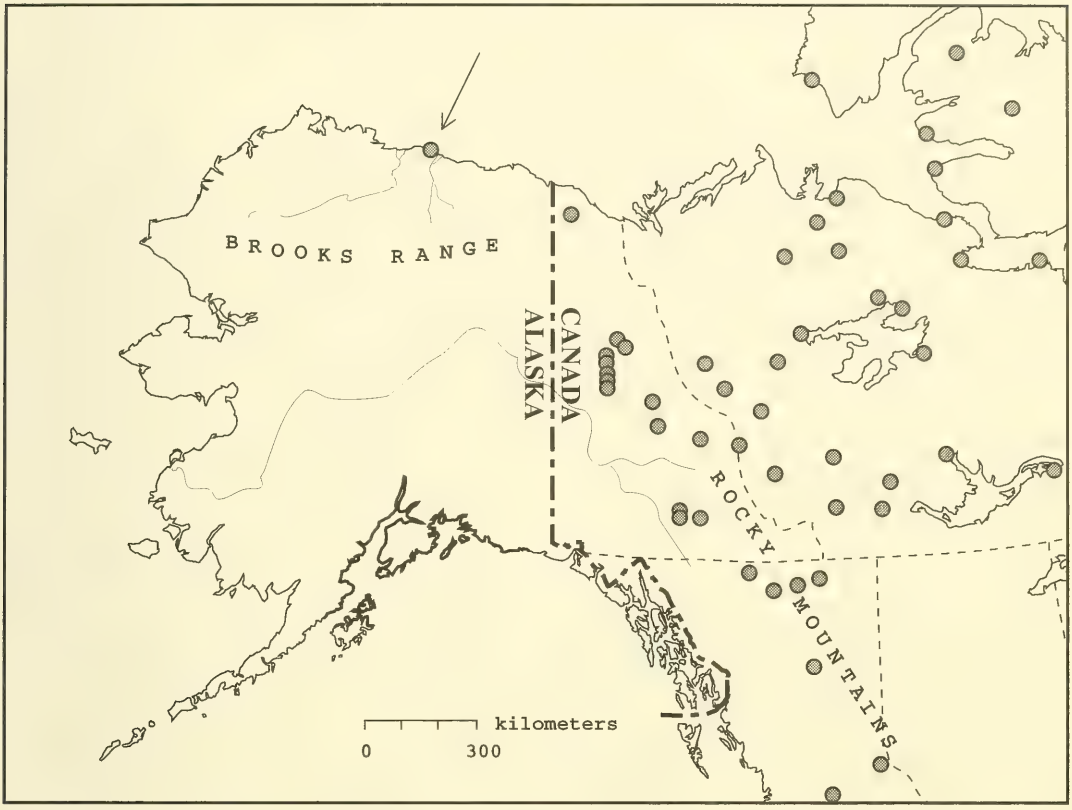


FIGURE 1. Collection sites for *Saxifraga aizoides* in western North America. Canadian collections compiled from maps in Porsild (1957), Hulten (1968), Porsild and Cody (1980), and from recent collections mapped by W. J. Cody. The new collection from Prudhoe Bay, Alaska is indicated by the arrow.

summer (1989) that *S. aizoides* was collected in Alaska it was also collected in the British Mountains in northwestern Yukon Territory, very near the Alaskan border (W. J. Cody, personal communication; Figure 1).

S. aizoides at Prudhoe Bay may be in the early stages of establishment as only a single plant was found in a large scale plant survey of disturbed habitat along the peat road system in both 1988 and 1989, and with intensive field work throughout the region for well over a decade. It seems likely that the species may also occur somewhere in the Brooks Range, as it typically occurs along mountain streams (Hulten 1968), and on moist calcareous clays, gravels, and rocky ledges across the Canadian arctic and in the Rocky Mountain cordillera (Porsild 1957; Scoggan 1978; Porsild and Cody 1980). Its occurrence at Prudhoe Bay might thus be easily explained by seed washing down from the mountains to the south. The plant, however, was found along the Putuligayuk River which is a small tundra stream originating in the coastal plain. A direct line of abiotic dispersal from the Brooks Range is therefore not present in this case. Another possibility is that seed was brought in from the south and east in the Rocky Mountains (or from the Brooks Range) by seed eating migratory birds such as Lapland Longspurs, *Calcarius lapponicus*. These passerine birds migrate to northern Alaska via routes which take them directly through the Rocky Mountains (Irving 1961; West et al. 1968; Johnson and Herter 1989), and are particularly abundant in the Prudhoe Bay region where they spend large amounts of time foraging along the peat roads. Foraging is especially concentrated along the peat roads just after the birds arrive in early spring, as the elevated roads are generally blown free of snow when adjacent tundra is still snow covered (Troy 1991). This seed dispersal scenario is consistent with the pattern of range extensions for *S. aizoides* in the Yukon Territory in which the range has recently been extended north and westward along the Rocky Mountain Cordillera. It will be interesting to discover whether or not *S. aizoides* is eventually found to occur in the Alaskan portion

of the Rocky Mountain Cordillera (i.e. the Brooks Range).

Acknowledgments

Field work at Prudhoe Bay was conducted during a study of bird use of the peat roads for BP Exploration Inc. I am grateful to Declan Troy (of Troy Ecological Research Associates) for the opportunity to study the vegetation of the peat roads at Prudhoe Bay, and to Dave Murray (University of Alaska Museum) and Donald Walker (Institute of Arctic and Alpine Research) for encouraging the publication of this finding. I want to thank Dave Murray for confirming the identification, and both Dave Murray and W. J. Cody (Biosystematics Research Centre, Agriculture Canada) for comments and suggestions which greatly improved the presentation of this note. Many thanks to John Damuth (University of California, Santa Barbara) for the computer generated template for Figure 1.

Literature Cited

Argus, G. W. and **K. M. Pryer.** 1990. Rare vascular plants in Canada: our natural heritage. Rare and endangered plants project, Botany Division, Canadian Museum of Nature, Ottawa.

Douglas, G. W., G. W. Argus, H. L. Dickson and **D. F. Brunton.** 1981. The rare vascular plants of the Yukon. A Canadian contribution to the UNESCO program on man and the biosphere.

Halliday, G. 1977. New and notable finds in the Alaskan vascular flora. Canadian Field-Naturalist 91: 319–322.

Hulten, E. 1968. Flora of Alaska and neighboring territories. Stanford University Press, Stanford, California.

Irving, L. 1961. The migration of lapland longspurs to Alaska. Auk 78: 327–342.

Johnson, S. R., and **D. R. Herter.** 1989. The birds of the Beaufort Sea. BP Exploration Inc., Anchorage, Alaska.

Murray, D. F. 1978. Vegetation, floristics, and phytogeography of northern Alaska. Pages 19–36 *in* Vegetation and production ecology of an Alaskan arctic tundra. *Edited by* L. L. Tiezen. Springer-Verlag, New York.

Porsild, A. E. 1951. Botany of southeastern Yukon adjacent to the canol road. National Museums of Canada Bulletin Number 121 Ottawa.

Porsild, A. E. 1957. Illustrated flora of the Canadian arctic archipelago. National Museums of Canada Bulletin Number 146. Ottawa.

Porsild, A. E., and **W. J. Cody.** 1980. Vascular plants of continental Northwest Territories, Canada. National Museums of Canada, Ottawa.

Scoggan, H. J. 1978. The flora of Canada. National Museums of Canada Publications in Botany Number 7. Ottawa.

Troy, D. M. 1991. Bird use of disturbed tundra at Prudhoe Bay, Alaska: bird and nest abundance along the abandoned peat roads, 1988–1989. Troy Ecological Research Associates, Anchorage, Alaska.

Walker, D. A. 1985. Vegetation and environmental gradients of the Prudhoe Bay region, Alaska. U.S. Army CRREL report 85–14, Hanover, New Hampshire.

West, G. C., L. J. Peyton, and **L. Irving.** 1968. Analysis of spring migration of lapland longspurs to Alaska. Auk 85: 639–653.

Received 16 January 1991
Accepted 3 June 1992

Record of a Redhead, *Aythya americana*, Laying Eggs in a Northern Harrier, *Circus cyaneus*, Nest

JOSEPH P. FLESKES

United States Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Route 1, Box 960, Jamestown, North Dakota 58401

Present address: United States Fish and Wildlife Service, Northern Prairie Wildlife Research Center, 6924 Tremont Road, Dixon, California 95620

Fleskes, Joseph P. 1992. Record of a Redhead, *Aythya americana*, laying eggs in a Northern Harrier, *Circus cyaneus*, nest. Canadian Field-Naturalist 106(2): 263–264.

An active Northern Harrier, *Circus cyaneus*, nest containing Redhead, *Aythya americana*, eggs, found in an Alberta wetland, apparently represents the first record of a Redhead parasitizing a harrier.

Key Words: Northern Harrier, *Circus cyaneus*, Redhead, *Aythya americana*, parasitism, nest, parasitic egg-laying.

Redheads, *Aythya americana*, often lay eggs in nests of other species with which they share nesting habitats (Friedmann 1932). Weller (1959) lists 12 species in the families Anatidae and Ardeidae that Redheads were known to parasitize. However, no Accipitridae are listed even though Northern Harriers, *Circus cyaneus*, and Redheads share nesting habitats (Bent 1937; Bellrose 1980). In addition, I was unable to find any report of eggs of another species in a Northern Harrier nest.

On 29 May 1983, I flushed a female Northern Harrier from a nest containing five harrier eggs and two Redhead eggs (Harrison 1984). The nest was located in the center of a 2 ha wetland, 11 km north and 1 km east of Viking, Alberta (53°11'N, 111°52'W). The nest was composed of dead cattails, *Typha latifolia*, built 20 cm above the water, and lined with wetland grasses.

I candled (Weller 1956) the eggs and determined that the Redhead eggs were incubated 7 and 11 days, and the five harrier eggs ranged in age between 8 and 14 days of incubation. Assuming a usual two day egg-laying interval for harriers with incubation usually starting after the second egg (Palmer 1988), I determined that at least one harrier egg was present in the nest before a Redhead egg was laid there.

On 9 June, I returned and flushed the female harrier from her nest, still containing the two Redhead eggs, now candled at 18 and 22 days, and the five harrier eggs. On 15 June, I returned, again flushing the female harrier off her nest, now containing one Redhead egg, aged at 23 days, and four harrier eggs that were also near hatching. I found no remains of the missing Redhead egg or harrier egg. I returned on 1 July, four days after heavy rains, and found two harrier eggs floating near the empty and flooded nest.

I could not determine the fate of the missing eggs and any could have been taken by predators or the harriers, or they could have hatched and shells removed by the harriers (Palmer 1988). If either of the Redhead eggs hatched, the precocial ducklings could have left the nest and survived. However, harrier chicks are altricial and if any hatched they would have been at the nest and probably drowned when it flooded.

The lack of other reports of Redhead eggs in harrier nests may be the result of the behavior rarely occurring, cases being missed because harriers remove parasitic eggs, or both. Northern Harriers do tolerate other non-raptor species nesting near their nests (Palmer 1988) and are probably vulnerable to parasitism by Redheads. However, the behavior to parasitize harriers may be rare in Redheads if the reproductive gains are low compared to the risk of being killed by a harrier returning to the nest. Harriers aggressively defend their nests against avian and mammalian predators (Palmer 1988), but their reaction to ducks at their nests is unknown.

Some cases of parasitism may be missed if harriers remove parasitic eggs from their nests. I found Redhead eggs missing from the nest and Laine (1928) similarly noted that eleven of twelve prairie chicken (species unknown) eggs that a Northern Harrier had presumedly adopted disappeared. However, in both cases the eggs could have disappeared for reasons other than being removed by the harriers. Also, the harrier did incubate the eggs for some time in both cases indicating that harriers will accept eggs of another species in some situations.

The overall impact of Redhead parasitism of Northern Harrier nests on the productivity of either species is unknown, but it is probably minor.

Acknowledgments

I thank E. E. Klaas, D. L. Orthmeyer, J. Y. Takekawa, M. H. McNicholl, and an anonymous reviewer for their comments and R. J. Greenwood, and D. E. Sharp for their guidance and encouragement during field work.

Literature Cited

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pennsylvania. 540 pages.

Bent, A. C. 1937. Life histories of North American birds of prey. Part I. United States National Museum Bulletin. Number 170. (reprinted by Dover Publications, 1961). 482 pages.

Friedman, H. 1932. The parasitic habit in the ducks, a theoretical consideration. Proceedings of the United States National Museum 80 (18): 1–7.

Harrison, C. 1984. A field guide to the nests, eggs, and nestlings of North American birds. Collins Publications, Toronto. 416 pages.

Laine, W. H. 1928. Marsh Hawk hatches Prairie Chicken. The Canadian Field-Naturalist 42(2): 47.

Palmer, R. S. 1988. Handbook of North American birds. Volume 4. Yale University Press, London. 433 pages.

Weller, M. W. 1956. A simple field candler for waterfowl eggs. Journal of Wildlife Management 20: 111–113.

Weller M. W. 1959. Parasitic egg laying in the Redhead (*Aythya americana*) and other North American Anatidae. Ecological Monographs 29: 333–365.

Received 7 February 1991
Accepted 14 April 1992

First Report of the Threespine Stickleback, *Gasterosteus aculeatus*, from Sable Island

DAVID J. MARCOGLIESE

Department of Fisheries and Oceans, Maurice Lamontagne Institute, P.O. Box 1000, Mont-Joli, Quebec G5H 3Z4

Marcogliese, David J. 1992. First report of the Threespine Stickleback, *Gasterosteus aculeatus*, from Sable Island. Canadian Field-Naturalist 106(2): 264–266.

The euryhaline Threespine Stickleback, *Gasterosteus aculeatus*, is reported for the first time from ponds on Sable Island, located 290 km east of Halifax, Nova Scotia. This species was recovered from Middle Wallace Lake, East Wallace Lake and a small brackish pond just north of Wallace Lake. These fish may be recent introductions, or, alternatively, remnants of populations which occurred over an island archipelago which existed in offshore Nova Scotia during glacial and post-glacial times.

Key Words: Threespine Stickleback, Fourspine Stickleback, Ninespine Stickleback, *Gasterosteus aculeatus*, *Apeltes quadracus*, *Pungitius pungitius*, Sable Island, glacial refugium, colonization.

Sable Island is a crescent-shaped emergent sand bar situated on the Scotian Shelf, approximately 290 km east of Halifax, Nova Scotia (Figure 1). The island is 39 km long and 1.5 km wide, and contains a number of enclosed ponds, most of which are quite brackish. Previously, four species of fishes have been reported from ponds on the island (Garside 1969). These fishes, known for their euryhaline tolerances (Scott and Crossman 1973), include the Mummichog, *Fundulus heteroclitis*; the Blackspotted Stickleback, *Gasterosteus wheatlandi*; the Fourspine Stickleback, *Apeltes quadracus*; and the Ninespine Stickleback, *Pungitius pungitius*. All four species were recovered from East Pond, and Mummichogs were also found in Main Pond, while Ninespine Sticklebacks were also found in Main Pond and Lily Pond (Figure 1). Fourspine Stickleback were also caught in Wallace Lake, the largest pond on the island (McAllister 1970). There are incidental sightings of "flounders" from Wallace Lake, and of the American Eel *Anguilla rostrata* from Main Pond (Garside 1969).

In August 1990, fishes were collected from Wallace Lake, Middle Wallace Lake, East Wallace Lake, Main Pond, and Pond "A" by dip net, beach seine, and baited minnow traps (Figure 1). Middle and East Wallace Lakes are incorporated into Wallace Lake during winter, or after heavy rains. Pond "A" is separated from Wallace Lake only by a small ridge of sand, and is often connected to it. Fishes captured included *A. quadracus*, the Threespine Stickleback *Gasterosteus aculeatus*, *P. pungitius*, the Northern Sand Lance *Ammodytes dubius*, and the American Plaice *Hippoglossoides platessoides* (Table 1). This is the first report of American Plaice, Sand Lance and Threespine Stickleback from Sable Island. Limited numbers of Sand Lance (1) and the American Plaice (4) were seined in East Wallace Lake, located quite close and often connected to the ocean. These probably represent sporadic introductions from the open ocean. Threespine Stickleback were recovered from Middle and East Wallace Lakes, and from Pond "A". Specimens ranged from 2.2 to 6.6 cm total length,

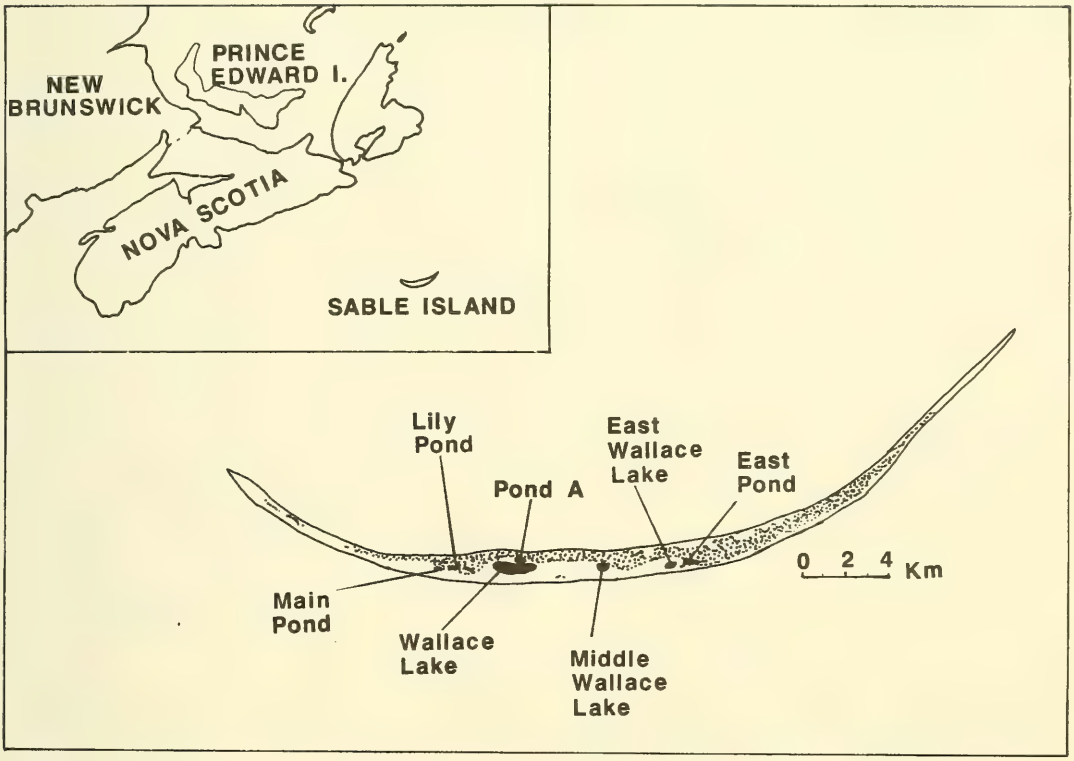


Figure 1. Map of Sable Island depicting collection localities mentioned in the text. Inset: location of Sable Island relative to Nova Scotia, Canada.

and all were of the marine form *G. a. trachurus*, characterized by a complete series of lateral bony plates and silvery colour (Scott and Crossman 1973). Specimens have been deposited in the Nova Scotia Museum collection (Accession number NSM10039).

It is surprising that *G. aculeatus* has not been reported from Sable Island previously. The reason may be that Middle and East Wallace Lakes, as well as Pond "A", were not sampled in earlier studies. It is possible that the Threespine Stickleback is a recent introduction. This species has been found occasionally on Scotian Shelf fishing banks, after being swept out to sea from inshore Nova Scotia areas (Scott and Crossman 1973), or perhaps it may have been carried by the nearby Gulf Stream from New England (McAllister 1970). Threespine Sticklebacks were found up to 110 km offshore in waters off New Jersey and New York (Cowen et al. 1991). When seen offshore, the Threespine Stickleback is usually in shallow water, associated with floating seaweed or debris (Scott and Scott 1988). Colonization of Sable Island by these displaced fish may have occured in the recent past. Similarly, the Mummichog, Fourspine Stickleback and Ninespine Stickleback on Sable Island are typically marine forms and could have conceivably colo-

TABLE 1. Presence of fishes in the ponds sampled on Sable Island in August 1990. (n)= number of fish collected.

Locality	Wallace Lake 43°55.6'N 59°59'W	Main Pond 43°56'N 60°01'W	Middle Wallace 43°55.8'N 59°56'W	East Wallace 43°55.8'N 59°53'W	Pond A 43°56'N 59°59'W
Gasterosteus aculeatus			+ (3)	+ (23)	+ (82)
Apeltes quadracus	+ (38)		+ (25)	+ (18)	+ (34)
Pungitius pungitius		+ (35)			
Hippoglossoides platessoides				+ (4)	
Ammodytes dubius				+ (1)	

nized the island by being carried offshore by storms or currents (McAllister 1970). Alternatively, the fish may be remnants of populations which inhabited an island archipelago that existed in offshore regions of Nova Scotia during glacial and post-glacial times (Bousfield 1962, 1970). The outer coasts of these islands would have escaped glaciation and provided a refugium for intertidal, terrestial, and freshwater species, including coastal euryhaline fishes (Bousfield 1962; Hamilton and Langor 1987). This hypothesis is supported by the presence of the stenohaline freshwater amphipod *Crangonyx richmondensis richmondensis* in freshwater ponds on Sable Island (Bousfield 1970).

Acknowledgments

David Sinclair and Johanne Guerin assisted in collecting fishes from Sable Island ponds. Brian Beck kindly provided and maintained the vehicles required for transportation around the island. John Gilhen (Nova Scotia Museum) confirmed the identification of *G. aculeatus*. Comments by Dr. Richard Arthur improved the manuscript.

Literature Cited

Bousfield, E. L. 1962. Studies on littoral marine arthropods from the Bay of Fundy region. Bulletin of the National Museum of Canada 183: 42–62.

Bousfield, E. L. 1970. Amphipod and isopod crustaceans. *In* Fauna of Sable Island and its geographic affinities. National Museum of Natural Science Publication in Zoology 4: 34–37.

Cowen, R. K., L. A. Chiarella, C. J. Gomez, and **M. A. Bell.** 1991. Offshore distribution, size, age, and lateral plate variation of late larval/early juvenile sticklebacks (*Gasterosteus*) off the Atlantic coast of New Jersey and New York. Canadian Journal of Fisheries and Aquatic Sciences 48: 1679–1684.

Garside, E. T. 1969. Distribution of insular fishes of Sable Island, Nova Scotia. Journal of the Fisheries Research Board of Canada 26: 1390–1392.

Hamilton, K. G. A., and **D. W. Langor.** 1987. Leafhopper fauna of Newfoundland and Cape Breton Islands (Rhynchota: Homoptera: Cicadellidae). Canadian Entomologist 119: 663–695.

McAllister, D. E. 1970. The fresh and brackish water fishes. *In* Fauna of Sable Island and its geographic affinities. National Museum of Natural Sciences Publication in Zoology 4: 38–43.

Scott, W. B., and **E. J. Crossman.** 1973. Freshwater fishes of Canada. Fisheries Research Board of Canada Bulletin 184.

Scott, W. B., and **M. G. Scott.** 1988. Atlantic fishes of Canada. University of Toronto Press, Toronto.

Received 21 March 1991
Accepted 6 March 1992

First Record of the Minke Whale, *Balaenoptera acutorostrata*, in Manitoba Waters

DONALD L. PATTIE[1] and MARC WEBBER[2]

[1]Northern Alberta Institute of Technology, 11762-106 Street, Edmonton, Alberta T5G 2R1
[2]Natural History Museum and Aquarium, Golden Gate Park, San Francisco, California 98114

Pattie, Donald L., and Marc Webber. 1992. First record of the Minke Whale, *Balaenoptera acutorostrata*, in Manitoba waters. Canadian Field-Naturalist 106(2): 266–267.

A Minke Whale, *Balaenoptera acutorostrata*, was seen in Button Bay, near Churchill, Manitoba on 31 July 1990. This represents the first report of a living Minke Whale in Hudson Bay. Two days later a small pod of Killer Whales, *Orcinus orca*, was seen in a northern part of Hudson Bay.

Key Words: Minke Whale, *Balaenoptera acutorostrata*, Killer Whale, *Orcinus orca*, marine mammals, Manitoba mammals, Hudson Bay.

The Minke, or Little Piked Whale, *Balaenoptera acutorostrata* Lacepede, has never been reported from Hudson Bay. There is however, a report of a Minke Whale carcass from James Bay (Abraham and Lim 1986). Banfield (1974) showed the western boundary of Ungava Bay as the limit of the Minke Whale range in northeastern Canada.

On 31 July 1990, during a visit to Fort Prince of Wales at the mouth of the Churchill River we observed a Minke Whale, through binoculars, in Button Bay at 58°45'N, 94°23'W. A narrow peninsula, on which Fort Prince of Wales stands, separates Button Bay from the Churchill River. Churchill, Manitoba lies immediately across the Churchill

River from the Fort. The whale surfaced four times near shore. Each time the dorsal fin was clearly apparent. No flukes appeared above the surface when it sounded. The presence of the dorsal fin served to distinguish the Minke Whale from Beluga Whales, *Delphinapterus leucas* (Pallas), and the tendency to sound without revealing the flukes is characteristic of the Minke Whale. This record extends the distribution of a living Minke Whale nearly 1600 km to the west and south of former records and augments the report by Abraham and Lim (1986).

Minke Whales are known to feed extensively on Capelin, *Mallotus villosus*, cod, *Gadus morhua*, and other shoaling fish (Horwood 1990; Johnsgard 1982) and to follow spawning Capelin northward (Mitchell and Kozicki 1975). The sites where rivers flow into the west side of Hudson Bay are associated with spawning Capelin concentrations during July (Liem and Scott 1966). Large numbers of Belugas traditionally enter the Churchill River at this time and Belugas are known to feed on Capelin (Watts and Draper 1986). We observed more than 40 Belugas in the Churchill River as we crossed from Churchill to Fort Prince of Wales where the Minke Whale was seen.

Cod have recently been exposed to heavy fishing pressure around Newfoundland and Labrador (Horwood 1990). Minke Whales have traditionally fed on Cod (Sergeant 1963) and it may be that a shortage of traditional Cod stocks served as an inducement for the whales to enter less traditional waters. An anonymous reviewer of this note suggested as an alternate hypothesis that Minke Whales have not been hunted in Newfoundland/Labrador since 1972 and our observation is simply a reflection of an expanding population extending its range. He commented further that Capelin have been very abundant since 1981. We must point out that Minke Whales were seldom harvested before 1960 and, despite their abundance then, there are no early records of that species in Hudson Bay.

A week prior to our observation of the Minke Whale in Button Bay we observed three Minke Whales rolling vigorously at the surface between Goodwin and Lacy Islands, two of the Button Islands at 60°42'N, 64°38'W. That group appeared to be feeding in association with several pods of 50–100 Harp Seals, *Phoca groenlandica*, flocks of Black-legged Kittiwakes, *Rissa tridactyla*, and Northern Fulmars, *Fulmarus glacialis*. These were seen in a region of violent upwelling associated with the changing of the tide. This Button Island observation is near the previously reported western range limit of the Minke Whale except for the James Bay observation.

Two days after the Minke Whale was seen in Button Bay M. W. saw a small pod of three or four Killer Whales [*Orcinus orca* (Linnaeus)] in northern Hudson Bay between Marble Island and Walrus Island. Killer Whales have been seen before in Hudson Bay, but we could speculate that their presence in late summer of 1990 was correlated with conditions that also brought the Minke Whale into Hudson Bay.

It is to be hoped that the Minke Whale sightings in 1986 and again in 1990 will encourage future travelers in Hudson Bay to watch for the species.

Acknowledgments

Three anonymous referees made suggestions to this note. We are grateful for their help.

Literature Cited

Abraham, K. F., and **B. K. Lim.** 1990. First Minke Whale, *Balaenoptera acutorostrata*, record for James Bay. Canadian Field-Naturalist 104(2): 304–305.

Banfield, A. W. F. 1974. The mammals of Canada. National Museum of Canada by University of Toronto Press. xxv + 438 pages.

Horwood, J. 1990. Biology and exploitation of the minke whale. CRC Press, Boca Raton, Florida. 238 pages.

Johnsgard, A. 1982. The food of minke whales (*Balaenoptera acutorostrata*) in northern Atlantic waters. Report of the International Whaling Commission 32: 259.

Liem, A. H., and **W. B. Scott.** 1966. Fishes of the Atlantic coast of Canada. Fisheries Research Board of Canada Bulletin 155. 485 pages.

Mitchell, E. D., and **M. V. Kozicki.** 1975. Supplementary information on minke whale (*Balaenoptera acutorostrata*) from Newfoundland fishery. Journal of the Fisheries Research Board of Canada 32(7): 985.

Sergeant, D. E. 1963. Minke whales, *Balaenoptera acutorostrata*, of the western North Atlantic. Journal of the Fisheries Research Board of Canada 20: 1489–1504.

Watts, P. D., and **B. A. Draper.** 1986. Note on the behavior of beluga whales feeding on capelin. Arctic and Alpine Research 18: 439.

Received 26 July 1991
Accepted 3 March 1992

Steller Sea Lion, *Eumetopias jubatus*, Predation on Glaucous-winged Gulls, *Larus glaucescens*

DONNA O'DANIEL[1,2] and JAMES C. SCHNEEWEIS[1,3]

[1]U.S. Fish and Wildlife Service, Alaska Maritime National Wildlife Refuge, Box 5251 Naval Air Station, Adak, Alaska, FPO Seattle, Washington 98791-0009
[2]Present address: U.S. Fish and Wildlife Service, Johnston Atoll National Wildlife Refuge, Box 396, APO San Francisco, California 96305-5000
[3]Present address: Minnesota Department of Natural Resources, 1201 East Highway 2, Grand Rapids, Minnesota 55744

O'Daniel, Donna, and James C. Schneeweis. 1992. Steller Sea Lion, *Eumetopias jubatus*, predation on Glaucous-winged Gulls, *Larus glaucescens*. Canadian Field-Naturalist 106(2): 268.

We observed a Steller Sea Lion (*Eumetopias jubatus*) preying on Glaucous-winged Gulls (*Larus glaucescens*) in the eastern Aleutian Islands. To our knowledge, this is the first record of such behavior by this species.

Key Words: Steller Sea Lion, *Eumetopias jubatus*, Glaucous-winged Gulls, *Larus glaucescens*, Aleutian Islands, marine mammals.

Steller Sea Lions are "opportunistic predators" (Loughlin et al. 1987: 3), preying primarily on fish and cephalopods (Fiscus and Baines 1966; King 1964; Loughlin et al. 1987; Schusterman 1981). They also prey, at least occasionally, on marine mammals such as Harbor Seals (*Phoca vitulina)* (Pitcher 1981), and Northern Fur Seals (*Callorhinus ursinus*) (Gentry and Johnson 1981). In an extensive review of pinniped predation on birds, Riedman (1990) notes that at least nine species of otariids prey on birds. However, she does not report this behavior by Steller Sea Lions.

On 20 July 1990, we saw an adult male Steller Sea Lion holding a Glaucous-winged Gull in its mouth. It was in open water approximately 100 m from our position on a low bluff on Aiktak Island in the eastern Aleutian Islands (52°25'N, 164°50'W). The sea lion dove with the gull while approximately 12 Glaucous-winged Gulls hovered and landed directly over it. The gulls pecked at the sea lion each time it surfaced, shaking the dead bird. After approximately six dives, the sea lion surfaced, swallowed the gull and dove again. It reappeared within seconds, seized another Glaucous-winged Gull from the surface of the water and made about four more shallow dives with the newly caught gull in its mouth. At this time, the sea lion was joined by a smaller Steller Sea Lion. Soon thereafter we left the area.

Steller Sea Lions occur near breeding colonies of Glaucous-winged Gulls throughout the Aleutian Islands and may occasionally prey upon gulls.

Literature Cited

Fiscus, C. H., and **G. A. Baines.** 1966. Food and feeding behavior of Steller and California sea lions. Journal of Mammalogy 47: 195–200.

Gentry, R. L., and **J. H. Johnson.** 1981. Predation by sea lions on northern fur seal neonates. Mammalia 45: 423–430.

King, J. E. 1964. Seals of the world. British Museum of Natural History, London. 240 pages.

Loughlin, T. R., M. A. Perez, and **R. L. Merrick.** 1987. *Eumetopias jubatus*. Mammalian species, Number 283. American Society of Mammalogists. 7 pages.

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus*, in the Gulf of Alaska. Fisheries Bulletin 79: 467–471.

Riedman, M. 1990. The Pinnipeds: Seals, Sea Lions, and Walruses. University of California Press, Berkley, California. 439 pages.

Schusterman, R. J. 1981. Steller Sea Lion — *Eumetopias jubatus*. Pages 119–141 *in* Handbook of Marine Mammals, Volume 1: The Walrus, Sea Lions, Fur Seals and Sea Otter. *Edited by* S. H. Ridgeway and R. J. Harrison. Academic Press, London.

Received 17 May 1991
Accepted 7 April 1992

News and Comment

Amendment to the Constitution of The Ottawa Field-Naturalists' Club and Request for Additional Proposals

At the 114th Annual Business Meeting of The Ottawa Field-Naturalists' Club, held in Ottawa on 12 January 1993, the revised constitution published in *The Canadian Field-Naturalist* 106(1): 146-149 was adopted with one amendment. That amendment was to delete the last sentence in the third paragraph of "Article 9. Committees of Council". The deleted sentence had read: "The Nominating Committee and the Fletcher Wildlife Garden Committee are considered to be *ad hoc* committees."

In addition, although *The Canadian Field-Naturalist* 106(1) was delivered before the Annual Business Meeting it arrived less than one month before the date of that meeting. This technically breached the stipulation of Article 23 of the Constitution then in effect, requiring publication a full month in advance of a business meeting of any changes to the constitution. The Annual Business Meeting of 12 January 1993 voted to consider the revised Constitution but to inform the membership of an extended period for additional proposals. If any member feels that insufficient notice of the revised constitution was received to prepare an amendment, written amendments are now solicited.

Any specific amendment to the revised constitution, should be drafted in proposed form by a club member, seconded by a another member, and sent to the Club address before 30 June 1993. It will be published in *The Canadian Field-Naturalist* for consideration at the next Annual Business Meeting in January 1994.

FRANK POPE
President, The Ottawa Field-Naturalists' Club

Editor's Report for Volume 105 (1991)

A total of 98 manuscripts were submitted to *The Canadian Field-Naturalist* in 1990. Publication dates were 104(1) 31 July 1991, 104(2) 22 August 1991; 104(3) 24 January 1992, and 104(4) 24 August 1992. Volume 105 totalled 646 pages, the largest issue (4) was 188 pages. The number of research and observation contributions is summarized in Table 1, the totals for Book Reviews and New Titles in Table 2, and the distribution of published pages in Table 3. Review and preliminary editing of COSEWIC Status Reports on fish and marine mammals was again provided by Bob Campbell and appeared in 105(2) with page, table, and figure costs, as well as reprint charges, funded by the Department of Fisheries and Oceans. Tributes to the late James Alexander Calder and Stanley Warren Gorham appeared in 105(4). Mickey Narraway's computerization of reviewers continued to prove its worth. Wanda J. Cook diligently proof-read the galleys for the volume but is in no way responsible for errors or omissions at the page-proof stage; the latter are solely the fault of the Editor (as is, ultimately, everything in the journal). Bill Cody continued as business manager, assisted by Lois Cody, and their optimism and enthusiasm for the journal was particularly valued, as always. M.O.M. Printing, Ottawa, set and printed the journal and my special thanks are due Emile Holst and Eddie Finnigan and their staff. Two mainstays in the production of the journal continued their special con-

TABLE 1. Number of articles and notes published in *The Canadian Field-Naturalist* Volume 105 (1991) by major field of study.

Subject	Articles	Notes	Total
Mammals	19*	17	36*
Birds	13	7	20
Amphibians and reptiles	3	7	10
Fish	8**	4	12**
Invertebrates	3	3	6
Plants	8	4	12
Other	7***	0	7***
Totals	64	44	108

*Includes seven COSEWIC marine mammal Status Reports.
**Includes five COSEWIC fish Status Reports.
***Includes a Fish and Marine Mammal subcommittee report; a report on fire history, land use history and landscape pattern in Michigan; and one paper which combined birds and mammals and four papers in the News and Comment section, one on components of the economic value of Wildlife in Alberta, two major tributes and one separate list of publications.

TABLE 2. Number of reviews and new titles published in Book Review section of Volume 105 by topic.

	Reviews	New Titles
Zoology	57	81
Botany	13	46
Environment	22	60
Miscellaneous	7	17
Young Naturalists	0	61
Totals	99	265

TABLE 3. Number of pages published in *The Canadian Field-Naturalist* Volume 105 (1991) by section (number of manuscripts in parenthesis).

Issue number:	- 1 -	- 2 -	- 3 -	- 4 -	Total
Articles	100(17)	123(17)	71(12)	102(14)	396(60)
Notes	26(12)	20(10)	27(14)	18 (8)	91(44)
News and Comment	2 (6)	3 (2)	25(16)	20(10)	50 (34)
Book Reviews*	22(24)	17(20)	20(24)	28(31)	87(99)
Index	——	——	——	20 (1)	20 (1)
Advice to contributors	——	1 (1)	1 (1)	——	2 (2)
Total pages:	150	164	144	188	646

*Total pages for book review section include both reviews and new titles listings but parenthesis figures include only number of reviews.

the calendar year: G. W. Argus, V. G. Barnes, Jr., J. R. Bider, D. M. Bird, D. A. Boag, G. R. Bortolotti, R. J. Brooks, I. Brodo, R. G. B. Brown, D. L. Brunton, G. V. Byrd, R. W. Campbell, L. N. Carbyn, P. M. Catling, W. J. Cody, F. Cooke, P. R. Croskery, E. J. Crossman, F. Dean, A. Downes, J. Dubois, B. Fenton, B. Freedman, J. H. Gee, V. Geist, F. F. Gilbert, J. Gilhen, D. M. Green, V. L. Harms, Evan B. Hazard, S. M. Herrero, R. G. Holmberg, R. R. Ireland, R. D. James, R. D. Kathman, R. B. King, G. Kolenosky, K. W. Larsen, L. E. Licht, J. Lien, C. C. Lindsey, H. G. Lumsden, A. Martel, M. K. McNicholl, L. D. Mech, S. Miller, D. Nagorsen, J. S. Nelson, R. W. Nero, M. E. Obbard, M. J. Oldham, R. O. Peterson, M. Poulin, P. Prestrud, W. B. Preston, R. M. Raine, L. L. Rogers, R. C. Rosatte, D. B. O. Savile, D. Secoy, R. R. Snell, W. B. Scott, C. Schaadt, F. W. Schueler, R. O. Stephenson, K. W. Stewart, J. B. Theberge, P. Watts, W. F. Weller, C. Werschier.

tributions, Wilson Eedy as book review editor and Harvey Beck as Index compiler. George La Roi coordinated the Biological Flora of Canada. Our associate editors in 1991 were C. D. Bird, B. W. Coad, A. J. Erskine, W. E. Godfrey, D. Laubitz, W. B. McGillivray, W. O. Pruitt, Jr., S. M. Smith, and R. R. Campbell, the latter newly appointed this year. At the end of 1991, Bruce McGillivray stepped down because of pressure of other duties after serving two years as an associate editor. His contribution will be greatly missed. However, Tony Erskine, who played a reduced editorial role in 1991 because of the pressures of completing the Maritime Breeding Bird Atlas project, will have more time to devote to *Canadian Field-Naturalist* reviews in the coming year. I am indebted to all for their support and contributions.

In addition to the associate editors, the following reviewers evaluated one or more manuscripts though

My thanks are due President Roy John of the Ottawa Field-Naturalists' Club, the Club Council, Chairman Ron Bedford and the Publications Committee of the OFNC for their support, and the Canadian Museum of Nature for space and time when other duties permitted. Joyce provided encouragement and, most importantly, perspective throughout the year.

FRANCIS R. COOK
Editor

Errata for *The Canadian Field-Naturalist* 105(4)

Savard, Jean-Pierre L., and Pierre Lamonthe. 1991. Distribution, abundance, and aspects of the breeding ecology of Black Scoters, *Melanitta nigra*, and Surf Scoters, *M. perspicillata*, in northern Quebec. Canadian Field-Naturalist 105(4): 488–496.

The boundary of Labrador was inadvertently omitted from Figure 3, and "and Labrador" omitted from Table 7 where it should be inserted after the word "Quebec". Editorial apologies are due to R. Ian Goudie, Surrey, British Columbia, and any others similarly offended.

Lang, Anthony L. 1991. Status of American Coot, *Fulica americana*, in Canada. Canadian Field-Naturalist 105(4): 530–541.

Several author's galley corrections were inadvertently omitted from this paper.

In Figure 2 (page 533) labels under the x-axis of the two lower graphs are missing. These should have stated that the numbers on this axis are the last two digits of years, 1954 to 1986.

Table 1, referred to on page 534 and subsequently, was omitted. It is reproduced below.

TABLE 1. Population trends of the American Coot along Breeding Bird Survey routes in areas with significant changes ($p < 0.01$) (1966, 1976, or 1968 to 1988).

Area	% annual change (median)	% change since counts started	No. routes	Ave no. birds/route
Stratum 16	–4.823	–66.294	19	0.15
Stratum 64	15.739	1760.349	18	2.15
British Columbia	15.863	1742.429	14	2.47
E.N. America	–4.791	–66.044	83	0.24
FWS Region 4	–12.739	–95.244	34	0.70

An apology is also due for the poor quality of reproduction of Figure 1 (page 532), particularly in the central hatched area, in some copies of this issue. All authors are urged to supply ultra-sharp originals to enhance the likelihood of clarity for drafted figures that may be electronically scanned and reduced from their submitted size.

FRANCIS R. COOK
Editor

The Arctic Collection of the Fowler Herbarium, Queen's University, 1828–1977

A. Crowder, J. Topping, A. E. Garwood, M. Handford, C. Vardy and H. Bretzke

Department of Biology, Queen's University, Kingston, Ontario K7L 3N6

Crowder, A., J. Topping, A. E. Garwood, M. Handford, C. Vardy, and H. Bretzke. 1992. The arctic collection of the Fowler Herbarium, Queen's University, 1828–1977. Canadian Field-Naturalist 106(2): 272–277.

The Fowler Herbarium at Queen's University in Kingston is a collection containing about 140 000 specimens, founded in the 1860s. Two curators have been responsible for its periods of rapid expansion, James Fowler, the first professor of Botany at Queen's, during 1880 to 1907, and Roland Beschel during 1959 to 1971. (A comprehensive history of the Biology Department at Queen's University is presented by Smallman et al. 1991). Between these periods the collection was neglected and packed into boxes after the university museum, once housing a mixed collection of plants, geological specimens, insects, bones and classical sculpture, was broken up (L. Teather, University of Toronto, personal communication 1990). Only a few letters have survived as written records from before 1959. The collection has been housed in Earl Hall since 1966.

In 1988 computerization of the information on specimen labels in the Fowler Herbarium was begun, using an Altair AT clone computer with 90 megabyte storage capacity, and a program developed from PCFile+. Our method is among those discussed by Russell et al. (1989) in *A census of phytogeographic databases in North America,* a preliminary report for the Flora of North America Specimen Database Survey. It permits searches to be made taxonomically, by collectors, by date or by location.

In addition to use in teaching and research, a collection has value as a scientific archive. The interests of its curators, and their interaction with other organizations, locally, nationally and internationally, can be deduced from the scattered and incomplete records on labels. Obviously, if correspondence survives the task of unravelling the history of a collection is easier. When the collection of mosses at Queen's University was sorted taxonomically a card index was used to compile information on collectors (Crowder 1974). This paper is based on the first section of the collection to be computerized, the "arctic" material added to the collection before 1977, some 5800 specimens. "Arctic" was arbitrarily defined by Beschel as (1) north of 60°N, and (2) including Alaska, although parts of Alaska are well south of 60°N (see Figure 1). When the more southerly part of the collection has been computerized it will be possible to examine the provenance of specimens from the sub-arctic.

The Flora

About 250 specimens are non-flowering plants, including horsetails, lycopods and ferns. The most frequently collected flowering plants have been grasses and sedges, while dwarf willows, dwarf birches and shrubs such as *Cassiope* are well represented. The most frequently collected colourful tundra flowers include saxifrages, poppies and potentillas.

Sites

All collecting sites which could be located exactly are shown on Figure 1; a full list of named sites is available from the authors. Over 3300 specimens are from the Northwest Territories, 1660 from Greenland, 500 from Alaska and only 188 from the Yukon (cf. Table 1). The largest collections from the islands are 1481 from Baffin Island, 644 from Axel Heiberg Island, and 488 from Ellesmere Island. In the 1960s, one of the sites of intensive collecting was the Juneau Icefield in Alaska, because Michigan Institute of Glaciology has a field station there.

Collectors

A list of collectors is available from the authors. The largest individual collections were made by R. Beschel (1985 specimens), P. J. Webber (615), R. Hainault (851) and G. Brassard (370). The wealth of European botanical tradition is attested by the size of many Danish exchanges such as 279 from C. Hansen, 104 from K. Hansen and 110 from J. Johansen.

Exploration and expansion

The earliest specimens from the Canadian mainland are from the Mackenzie River at latitude 66°N, collected by James Anderson Esq., in 1852. It is possible that this was the James Anderson who was a Chief Factor of the Hudson's Bay Company; he canoed from Fort Resolute to the arctic coast in 1855, searching for the remains of the Franklin Expedition, and was later in charge at Moose Factory (Anonymous 1928; Dunbar and Greenaway 1956). The plants were labelled by Fowler, and on one he added the name "Barnstead", which also appears on an undated specimen from Hudson's Bay.

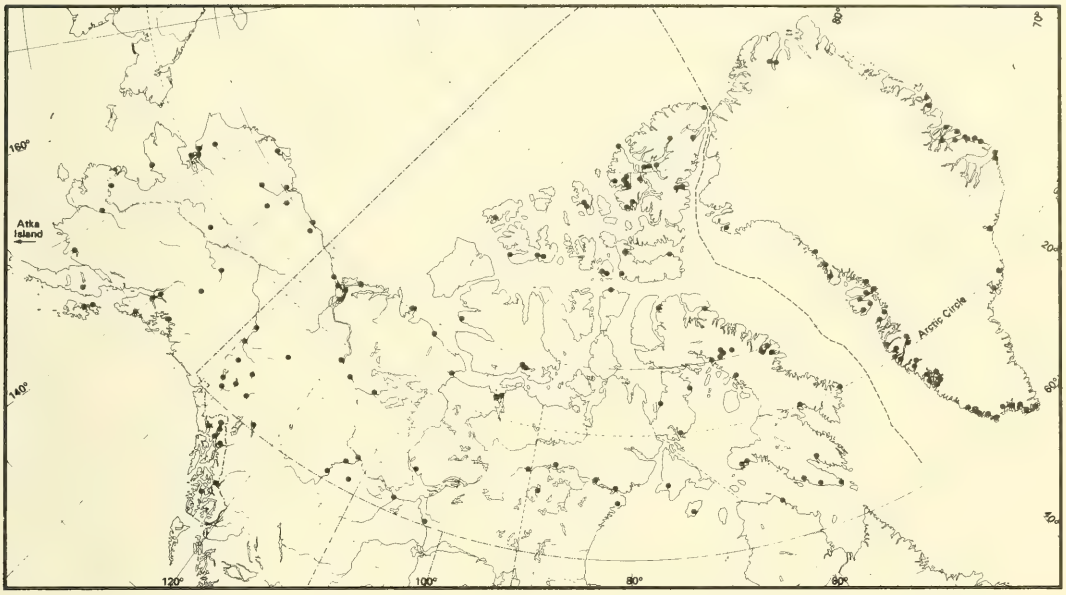


FIGURE 1. Sites of collections made during 1828 to 1977 in Canada north of 60°N, in Alaska and in Greenland.

The rivals of the Hudson's Bay Company, the Northwest Company, built two forts on the Mackenzie, Fort Simpson and Fort Good Hope, where specimens were collected in 1861. The collector's name is so far indecipherable, but the specimens were labelled "Explorations in Subarctic America" and were exchanged by G. W. Clinton, a correspondent of Fowler's who lived in New York State (Humphrey 1961; Crowder 1974).

The west coast of Greenland had whaling and fishing settlements and our earliest arctic material was collected there in 1828 and 1829 at Igaliko, Niakornaki and Nanortalik by J. Vahl. Vahl was mentioned as a collector in an account of the flora of Greenland written in 1884 (Berlin 1884). A grass specimen was collected by L. K. Rodenvinge at Upernavik, then the most northerly outpost on the west coast of Greenland, in 1886 (Banks 1975); Rodenvinge was later known as a pioneer collector of mosses from Greenland.

Disko and Godhavn, also west coast ports, were collection sites in 1905 (J. Kleist) and also in this region, close to 70°N, a specimen was collected by a Peary expedition in 1896. No collector's name is on that label, but Peary's polar voyage of 1908 and 1909 has also provided plants, and they were collected by R. Bartlett. Robert Bartlett was a member of a fishing and whaling dynasty from Newfoundland, and the captain of Peary's ship, the *Roosevelt* (Horwood 1977). The ship was built to the specifications of Admiral Peary, was specially reinforced against the ice of polar seas, and powered by both coal and sail. The plants were collected on Ellesmere Island, where the large expedition stayed, hunting for food and trophies. Bartlett, who accompanied Peary on his trek to the Pole in 1909, collected for several museums during his career, including the American Museum of Natural History, the New York Botanical Gardens and the Field Museum in Chicago (Horwood 1977).

Specimens from the less hospitable east coast of Greenland were collected by Norwegian expeditions in 1929 and 1932, and exchanged by the University Museum at Oslo. Plants from the extreme north, Astrop Fjord at 81°N and Bronlund Fjord north of 82°, were collected by a Danish expedition to Pearyland in 1947-1950 and exchanged by the Botanical Museum of the University of Copenhagen.

Sporadic exploration was superseded by systematic collection when the Greenland Botanical Survey was set up by the Botanical Museum of the University of Copenhagen (Hauniense) in the 1960s, and the flora was sufficiently well known for sets of exsiccatae to be exchanged (labelled *Plantae vasculares groenlandicae exsiccatae*). By the 1970s travel in Greenland had become sufficiently ordinary for collections to be sent to us by students from Carleton University and boys from Westminster School (cf. Table 1). Similarly, on the Canadian mainland the Thelon River, in the Barren Grounds, where John Hornby and his companions had starved to death in 1927 (Whalley 1977), was accessible for botanizing in 1965. G. Rossback collected there, at Baker Lake and at Aberdeen River.

TABLE 1. Numbers of specimens collected by decade, in Canada, Greenland and Alaska.

Date	Specimens Collected in CANADA	Specimens Collected in GREENLAND	Specimens Collected in the USA
1820-1830		2	
1831-1840		1	
1841-1850			
1851-1860	2	1	
1861-1870			2
1871-1880			2
1881-1890		1	3
1891-1900		2	
1901-1910	2	2	
1911-1920			
1921-1930	2	84	
1931-1940	32	35	1
1941-1950	24	34	44
1951-1960	755	559	24
1961-1970	2542	921	452
1971-1980	203	24	106
TOTALS	3562	1666	634

Expansion of collecting areas in Greenland was obviously due to improved transport. In Peary's time a ship locked in winter ice could provide a base for keeping plants dry, but after World War II air transport and tracked vehicles enabled ecologists to complete field work and get home within weeks. Table 1 shows the rapid expansion of collections after air strips and bases had been built. Botanists often collected right beside an airstrip, our first being I. Wiggins at Barrow, Alaska, in 1950. Other airstrips named were at Cornwallis Island, Cambridge Bay, Cape Dyer, Ellesmere Island, Tuktoyaktuk and Stromfjord Haven.

Road transport is evident by 1957 when W. B. Schofield collected along the Haines Highway, and with H. Crum along the Alaska Highway in the Yukon. By 1966 a curator of the Fowler Herbarium, Harold Zavitz, could combine botanizing with holidaying along the Alcan Highway.

The first mention of a permanent arctic research station on a label is from Greenland, where M. P. Porsild of the Copenhagen Museum worked at *Den Danske Arktiske Station* at Disko, in 1941. During the Cold War the desire to display sovereignty and the maintenance of permanent bases increased support for scientific research. The base at Barrow, Alaska, and several weather stations and communication centres are named as sites. Sponsorship included publication of G. Brassard's plant lists from Ellesmere Island by the Canada Defence Research Telecommunication Establishment (Brassard 1968), and of I. Wiggins' collection in Alaska by the United States Office of Naval Research, while in 1975 a collection was made from H. M. C. S. *Protecteur* on an exercise called Norploy, by J. Jotcham of Acadia University.

In Alaska exploration followed the same type of pattern as further east. The first records are coastal, from Atka in the Aleutians, where the collector was Lucien M. Turner, who published a list of Alaskan plants in 1886. A few specimens are derived from independent collectors early in the twentieth century, but we have no large collection until that made by L. A. Spetzman, who worked at the Arctic Research Laboratory at Point Barrow in 1949. In 1950, I. Wiggins collected under contract to the Office of Naval Research and later for the Dudley Herbarium of Stanford University .

A few specimens came from W. H. Drury, with the U. S. Geological Survey's "Alaska Terrain and Permafrost Section Party". E. Hultén, a director of the Botanical Department of the Riksmuseum of Stockholm, botanized in the Brooks Range in 1960s, Beschel on the Juneau Icefield in 1964, 1965 and 1969, and G. Argus of the Canadian National Museum at Muir Inlet and other sites. In 1972 E. Little and L. A. Viereck of the Forest Service Herbarium of the U. S. Department of Agriculture made extensive collections.

The material from the Yukon has about the same balance of material from institutions and individuals as that from the Northwest Territories and Alaska.

People and Provenance

Fowler wanted a herbarium for teaching plant taxonomy and plant geography, so he set out to make contacts. Before coming to Queen's University, during his first career as a clergyman in New

Brunswick, he had set up correspondence with botanists in the United States (Beschel 1966; Crowder 1974). He was a member of the Natural History Society of Buffalo as early as 1866 (MacMillan 1987). The Buffalo contact explains exchanges from G. W. Clinton, who lived there; they included plants from the Mackenzie valley and from Greenland collected in the 1860s. During the period 1893-1907 Fowler's annual reports to the Principal of Queen's University described visits to the Smithsonian Institute in Washington, Johns Hopkins University, the University of Pennsylvania at Philadelphia, Columbia College in New York, Chicago University, the Arnold Arboretum, Yale, Cornell, and the Departments of Botany and Agriculture in Washington (Fowler 1893-1907). He had also botanized from Vancouver Island to Canso, and had gone to Europe bearing 1100-1200 specimens for exchange, apparently with Oxford and Cambridge. All this was at the university's expense, and he reported with glee that several hundred of his specimens were in Washington "treasured up in these vast collections". The fruits of his visits are apparent; for example some of the herbarium's earliest specimens from Alaska (collected by L. Turner) were exchanges from the U. S. Department of Agriculture and the U. S. National Herbarium, and the Peary specimens came via the Field Museum at Chicago. There is no evidence that Fowler had any special interest in the flora of the arctic or contact with explorers in the high arctic; he may have considered that he had sufficient representation of tundra vegetation from further south.

A group of "botanistes explorateurs" is apparent in the 1930s, collecting in the four vicariates of the Catholic missions in the arctic and subarctic, Mackenzie, Hudson's Bay, James Bay and Northern Quebec. The collecting sites of these "pères au foin" included Wakeham Bay and Chesterfield Inlet. The naturalist of the missions was Père Arthéme Dutilly O. M. I., and associated with him on some of his summer voyages were the Reverend Maximilian Duman O. S. B. and Dr. Gerard Gardner. In 1933 he used a tiny vessel called the *Pie IX* as a base for collecting, in 1939 the *Achaean* is named on a label, and in 1939 the mission also acquired the larger *Nouveau Quebec*. Dutilly became director of the Arctic Institute of the Catholic University of America at Washington, D. C. and his specimens and those of Duman were exchanged from there. Their sheets from the Herbier des Missions are decorated with elegant large-scale maps and ecclesiastical seals. Duman was based at St. Vincent's College, Latrobe, Pennsylvania (Dutilly and Lepage 1945-1947; Dutilly et al. 1953, 1945-1967; Gardner 1937; Lepage 1973).

Groups of taxonomists centred on museums are apparent in the collection, frequently verifying or correcting each other's identifications and sharing the same format of label. The names of ten botanists from Copenhagen and six from Oslo recur frequently, among them prominent taxonomists such as B. Fredskild, the current Keeper of the Greenland Herbarium at Copenhagen.

In Ottawa two groups of collectors can be distinguished from the 1920s on. The group from the National Museum of Canada includes M. O. Malte and A. E. Porsild, both former Chief Botanists; G. Argus of the Botany Section, S. D. MacDonald of the Zoology Section, and G. Hattersley-Smith. The second, from the Phanerogamic Herbarium of the Plant Research Institute of the Department of Agriculture (part of the Biosystematics Research Institute) included W. J. Cody, a former Curator, J. A. Calder, J. A. Parmelee and D. B. O. Savile. Another collector was J. Martin of the Entomological Research Section also part of the Biosystemics Research Institute. Collections were sometimes made under the aegis of these institutions by other than regular staff members, for example T. H. Manning, an independant biologist and M. Kuc, of the Geological Survey, collected for the museum. Throughout our collection the formative influence of Dr. Porsild is apparent, first as a collector, and then as a taxonomic expert.

The writings of the herbarium's contributors embody the development of arctic botany. Early collectors wrote checklists, and then regional floras; we have plants collected by the authors of floras of Greenland (Böcher et al. 1957; Hansen et al. 1967), of floras of the northwest territories and of the arctic islands (Porsild 1943, 1945, 1955, 1957; Porsild and Cody 1968), the eastern Arctic (Polunin 1948), and Alaska (Wiggins and Thomas 1962; Hultén 1968; Viereck and Little 1972). By 1959, Dr. Polunin, who was based at Oxford but maintained close links with the Canadian National Museum, could write about the circumpolar distribution of plants as a whole (Polunin 1959). A more specialized stage was reached with studies of one genus or family providing specimens, such as the willows (Argus 1965), the saxifrages (Calder and Savile 1959-1960) or the gentians (Gillett 1963). Current contributors to the collection are engaged not only in biogeography but in ecological topics such as herbivory and pollination.

In comparison to the collectors of mosses (Crowder 1974), those in the arctic numbered few amateurs and few women. Our earliest collection by a woman was made by Mrs. E. H. Loofe in Alaska in 1939. The expense and difficulty of arctic travel explain the absence of these groups but do not explain the high proportion of collectors who have become distinguished ecologists. Leacock recommended eating cold porridge from garbage cans as a recipe for becoming a millionaire, and it seems that a season of tundra botanizing is a good recipe for becoming a successful ecologist.

After Fowler's retirement, interest in the herbarium was slight until Roland Beschel arrived in 1959. The collection was then housed in dusty cupboards in the corridors of Theological Hall; the cupboards and the collection had been restored in 1941 by Roland Barnsley. In a manuscript report Barnsley (who described himself as an Arts student in the class of 1944) stated that the Fowler and university collections had been combined, dusted and sorted by genera in folders (cf. Boivin 1980). He estimated that there were about 48 000 mounted and 5000 unmounted specimens and implied that no curatorial work had been done between 1915 and 1941. Beschel had been educated in Vienna and Innsbruch and had already worked in the Maritimes and Greenland. His aims were to build up both the arctic and local holdings of the herbarium. He succeeded on both counts, adding specimens from his own extensive field travels, from colleagues and from an active network of national and international exchanges (Beschel 1966). Many of the exchanges were set up through personal contacts, in Beschel's day sponsored not by the university but by the National Research Council. Beschel's immediate group of research students, assistants and friends numbered at least 14 arctic collectors; they were the first direct link from Queen's with the tundra. Among them is the only Inuit named on labels, Panaktock, who worked with R. Hainault on a lake survey for the Fisheries Research Board of Canada in 1962. Beschel's field work resulted in several reports and papers such as Brassard and Beschel (1968) on Tanquary Fjord, and he supervised theses such as P. J. Webber's on the plant ecology of central Baffin Island.

Interaction between groups can be deduced from labels. The genus *Puccinellia,* a small grass, provides an example. In the 1960s, the world expert on its taxonomy was Dr. T. Sorensen, working in Copenhagen (Sorensen 1953). Specimens were sent to him for determination or verification by the museum in Ottawa and by Beschel (Queen's University records 1966). He gave a set of plants to the National Museum, which gave the plants accession numbers. Subsequently, tiny pieces of these plants were kindly given to the Fowler Herbarium, enough for comparisons to be made. Among our earliest material from Greenland is a grass acquired via this roundabout route of Copenhagen and Ottawa. The numbers and initials on such sheets unravel a method of work reminiscent of that of a master craftsman and his apprentices.

Acknowledgments

We wish to thank Carol Noël for preparation of this manuscript and Nancy Doubleday for information on James Anderson.

Literature Cited

Anonymous. 1928. Chief Factor James Anderson. The Beaver, 1928. December. page 122.

Argus, G. 1965. The taxonomy of the *Salix glauca* complex in North America. Contributions of the Gray Herbarium Harvard University 196: 1–142.

Banks, M. 1975. Greenland. David and Charles. Newton Abbott. 208 pages.

Berlin, A. 1884. Kärlväxter, insamlade under den svenska expeditionen till Grönland 1983. Ofversigt af Kongl. Vetenskaps-Akademiens Förhandlingar 1884 7. Stockholm.

Beschel, R. E. 1966. A history of the Biology Department and the Fowler Herbarium of Queen's University. Fowler Herbarium, Kingston, Ontario. 55 pages.

Böcher, T. W., K. Holmen, and **K. Jakobsen**. 1957. Grönlands Flora. P. Haase and Sons Forlag. Copenhagen. 313 pages.

Boivin, B. 1980. Survey of Canadian Herbaria. Provancheria 10: 85–87.

Brassard, G. 1968. Botanical studies in N. Ellesmere Island in 1967 telecommunications a preliminary report. Canada Defence Research Telecommunications Establishment. 10 pages.

Brassard, G. R., and **R. E. Beschel.** 1968. The vascular flora of Tanquary Fjord, northern Ellesmere Island, N.W.T. Canadian Field-Naturalist 82: 103–113.

Calder, J. A., and **D. B. O. Savile**. 1959-1960. Studies in Saxifragaceae. Brittonia 11: 49–67 [1959]. Canadian Journal of Botany 38: 409–438. [1960].

Crowder, A. 1974. The collection of bryophytes in the Fowler Herbarium, Queen's University, Kington, Ontario. Canadian Field-Naturalist 88: 47–55.

Dunbar, M., and **K. R. Greenaway.** 1956. Arctic Canada from the air. Defence Research Board, Queen's Printer, Ottawa.

Dutilly, A., and **E. Lepage.** 1945-1947. Coup d'oeil sur la flore subarctique du Québec. Le Naturalist canadien 72: 185–224, 266–288; 73: 419–435, 74: 43–60, 66–78, 177–188, 207–224, 250–272.

Dutilly, A., E. Lepage, and **M. G. Duman.** 1953. Contribution a la flore du bassin de la baie d'Ungave. Contributions of the Arctic Institute of the Catholic University of America 4F: 1–104.

Fowler, J. 1983-1906. Reports to the Principal of Queen's College. Queen's Quarterly 1: 89, 162; 2: 81; 3: 65; 4: 64; 5: 70; 6: 57; 7: 60; 8: 53; 9: 29; 10: 86; 11: 57; 12: 79; 13: 78; 14: 46.

Gardner, G. 1937. Listes annotees des especes de pteriodophytes, de phanerogames et d'algues recoltees sur la cote du Labrador, a la baie d'Hudson et dans le Manitoba nord, en 1930 et 1933. Bulletin Société Botanique de la France 84: 1–3.

Gillett, J. M. 1963. The gentians of Canada, Alaska and Greenland. Canada Department of Agriculture Publication 1180: 1–99.

Hansen, K. L., L. Klijm-Nielsen, and **N. Ollgren**. 1967. Plantae Grönlandicae. Grönlands Botany Undersogelse.

Horwood, H. 1977. Bartlett, the great Canadian explorer. Doubleday, Toronto. 194 pages.

Hultén, E. 1968. Flora of Alaska and neighbouring territories. Stanford University Press. Stanford, California. 1008 pages.

Humphrey, H. B. 1961. Makers of American Botany. Chronica Botanica 21. New York.

Lepage, E. 1973. Le père Arthéme Dutilly. Le Naturalist canadien 100: 327–329.

Little, E. L. 1971. Atlas of United States trees. U.S. Department of Agriculture, Forestry Service Publication. 1146.

MacMillan, G. 1987. Backwoods to baccalaureate and beyond. New/Nouveau Brunswick 12(1): 29–32.

Polunin, N. 1948. Botany of the Canadian eastern Arctic. Canada Department of Mines and Resources. National Museum of Canada Bulletin 104. 304 pages.

Polunin, N. 1959. Circumpolar Arctic Flora. Clarendon Press. Oxford. 511 pages.

Porsild, A. E. 1943. Materials for a flora of the continental northwest territories of Canada. Sargentia 4: 1–79.

Porsild, A. E. 1945. The alpine flora of the east slope of the Mackenzie Mountains, Northwest Territories. National Museum of Canada Bulletin 101. 35 pages.

Porsild, A. E. 1955. The vascular plants of the western Canadian Arctic Archipelago. National Museum of Canada Bulletin 133. 226 pages.

Porsild, A. E. 1957. Illustrated flora of the Canadian Arctic Archipelago. National Museum of Canada Bulletin 146. 209 pages.

Porsild, A. E., and **W. J. Cody.** 1968. Checklist of the vascular plants of continental Northwest Territories, Canada. Plant Research Institute, Canada Department of Agriculture, Ottawa.

Russell, G., E. Gibbs, and **L. A. Turner.** 1989. A census of phytogeographic databases in N. America. Missouri Botanic Garden, St. Louis. Missouri. 24 pages.

Sorensen, T. J. 1953. A revision of the Greenland species of *Puccinellia.* Meddelelser on Grönland 136: 1–179.

Smallman, B. N., H. M. Good, and **A. S. West.** 1991. Queen's Biology: An academic history of innocence lost and fame gained 1858-1965. Department of Biology, Queen's University of Kingston, Ontario. xiv + 215 pages.

Turner, L. M. 1886. Contributions to the natural history of Alaska. Senate Miscellaneous Document 155. 49th Congress 8 (1886).

Viereck, L. A., and **E. L. Little.** 1972. Alaskan Trees and Shrubs. U.S.D.A. Agricultural Handbook 410. 205 pages.

Webber, P. J. 1971. Gradient analysis of the vegetation around the Lewis Valley, north-central Baffin Island, N.W.T., Canada. Ph.D. thesis, Queen's University, Kingston, Ontario.

Whalley, G. 1977. The Legend of John Hornby. MacMillan, Toronto. 357 pages.

Wiggins, I., and **H. H. Thomas.** 1962. A Flora of the Alaskan Arctic Slope. Arctic Institute of North America Special Publication 4. University of Toronto Press.

Received 31 May 1991
Accepted 23 March 1992

Book Reviews

ZOOLOGY

Ecology and Classification of North American Freshwater Invertebrates

By James H. Thorp and Alan P. Covich, Editors. 1991. Academic Press (Harcourt Brace Jovanovich, San Diego). xii + 911 pp., U.S. $59.95.

This large (22 × 28.5 cm, 2.5 kilograms) book is a must for every aquatic biologist who works with the North American fauna, and should prove to be very useful to biologists from other regions, as well. It presents in one volume the most recent and comprehensive treatments of the ecology and (usually) generic-level taxonomy of all groups of aquatic invertebrates, written by authorities on each group. To prevent duplication of recent books on aquatic insects, and to keep this book from almost doubling in size, insects are treated only at the family level. On the other hand, several small groups (i.e., sponges, leeches) are treated at the species level. The book consists of 22 chapters; a glossary of taxonomic, biological, and ecological terms; and separate taxonomic and subject indices. It begins with an introductory chapter by the editors that consists of very brief characterizations of each phylum treated in subsequent chapters, and a key to the major taxa. The second chapter, also by the editors, is a well-written discussion of the diversity of freshwater habitats. Each of the remaining 19 chapters covers one of the major groupings of freshwater invertebrates. These chapters all are similar in layout, but not all identical. Each one usually begins with an overview of the group, followed by a brief discussion of anatomy and physiology, a detailed review of the ecology of the group, and finally the taxonomic section which includes keys to the higher taxonomic levels, and for most groups the genera. The information presented is uneven from one chapter to the next, which is a reflection of the amount of information available for the different groups, and probably the interests of the authors, as well. Thus, the chapter on bivalve molluscs, a group with approximately 260 species in North America that are often conspicuous and important components of aquatic ecosystems, devotes more than 50 pages to anatomy, physiology, ecology, and evolution, while the chapter on tardigrades, a cosmopolitan group of approximately 600 species that are almost never conspicuous nor considered important components of any ecosystem, devotes just 13 pages to similar topics. This is to be expected in a multi-authored volume (28 contributors including the editors) treating such a diverse array of organisms, and does not detract from the overall quality of the presentations. Each chapter is well illustrated with photographs and line drawings of the organisms themselves, as well as with tables, figures, and photographs that present taxonomic, ecological, or other information. A literature cited section follows the keys at the end of each chapter. This will serve as an excellent introduction to the most pertinent taxonomic and ecological literature on the various groups in North America for those needing to pursue groups in more detail.

My only complaint with the book is the lack of diagnoses for the taxa keyed. With the exception of the sponges, which are treated in detail at the species level, no detailed descriptions of the taxa, be they families or genera, are provided to help determine the reliability of identifications. This is unfortunate, but understandable. To have included detailed descriptions of each taxon keyed would no doubt have doubled the size of the book, which as is does not fit comfortably beside the microscope.

This is a "must have" book for aquatic biologists, and would serve very well as a text for a course on non-insect aquatic invertebrates. The up-to-date coverage, with its emphasis on ecology and classification, gives it a unique position among general purpose keys to aquatic organisms (eg., Ward and Whipple, Pennak) which I believe will appeal to many potential users. In addition, the book is well made and attractively designed. Considering the prices of books these days, sixty dollars is a bargain for such a volume. I strongly recommend *Ecology and Classification of North American Freshwater Invertebrates.*

CHARLES R. PARKER

Uplands Field Research Laboratory, Great Smoky Mountains National Park, Gatlinburg, Tennessee 37738

The Evolution of Parental Care

By T.H. Clutton-Brock. 1991. Monographs in Behavior and Ecology. Princeton University Press, Princeton. xiii + 352 pp., illus. Cloth U.S. $49.50; paper U.S. $19.95.

The phenomena associated with parental care are among the most intriguing in natural history. Some species of birds operate at four times their basal metabolic rate in order to feed nestlings. For large mammals, bears give birth to relatively small and few cubs, perhaps because of hibernation. Viviparity increases among lizards and snakes in higher latitudes, and no birds are live-bearing. Some female insects can determine the sex of each egg which they lay. While maternal fur seals and sea lions nurse their pups every few days between foraging trips for several months, true seals nurse continuously for a shorter period. African catfish parasitize cichlids which mouthbrood young of both species. Phenomena such as these receive a masterly analysis in the present work.

Edited by Tim Clutton-Brock and John Krebs, both well known and highly regarded behavioural ecologists, this series of monographs has already established its worth (see reviews in *The Canadian Field-Naturalist* 100: 295; 101: 503; 102: 749–750). In this volume Clutton-Brock enhances this reputation. From an evolutionary perspective the author links parental care with sexual selection and mate competition. Given definitions of key concepts (especially problematical "parental investment"), five basic questions are raised which underpin the subsequent chapters and are re-visited in the concluding chapter. Firstly the forms and costs of parental care across species and life stages are examined. Much of the evidence is only correlational (for instance, between components of fitness and with environmental features) and the needed experimental work is likely to be difficult.

Interspecific variation in parental care is the next focus. The size of propagules, presumably optimized by natural selection, is influenced by such factors as body size, environmental risks, and developmental and seasonal timing, as well as, of course, by parental care itself. The distribution of viviparity across taxonomic groups can be understood as the outcome of selection pressures involving harsh environments and intense intraspecific competition. Among endotherms, patterns of incubation, gestation, and lactation have received various explanations involving constraints and selection pressures on developmental processes. Thirdly the bases for parenting by one or both parents, or helpers, are considered. Comparative information provides insight into such matters as evolutionary routes for parental care, mating systems, problems of desertion and "cruel binds", and the roles of environmental conditions and modes of fertilization.

The study of the adjustment of parental care according to benefits to offspring and costs to parents, covered fourthly, is made difficult by ignorance of the underlying benefit and cost functions. Parental tactics can interact with availability of resources, access to mates, size of brood, and age and quality of offspring and parents. Conflicts between parents and offspring influence parental care and depend on both genetic and social factors. Relative parental investment in sons and daughters, the fifth topic, has impact at both the individual level, in terms of growth and survival, and the population level, in terms of demography and sex ratio. The concluding discussion usefully identifies theoretical and empirical needs which can advance understanding in this field.

Both the comprehensiveness and critical analysis of the material covered are impressive. The style of writing is very clear and the chapter summaries and abundant tables and figures support the text effectively. Throughout the book explicit hypotheses and models, both qualitative and quantitative, are carefully scrutinized; puzzling issues, such as polyandry and uniparental male care, and differential mortality between the sexes, are explored; and gaps in knowledge, often physiological, are highlighted. Robert Hinde, to whom the volume is dedicated, is justifiably honoured by this fine presentation.

PATRICK W. COLGAN

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Phylogeny, Ecology, and Behavior

By Daniel R. Brooks and Deborah A. McLennan. 1991. University of Chicago, Chicago. xii + 434 pp., illus. Cloth U.S. $45; paper U.S. $21.

For a number of years several convictions have been gaining momentum in comparative biology: that for systematics the phylogenetics of Willi Hennig is more powerful than the evolutionary approaches of the "modern synthesis" championed by such supporters as Ernst Mayr and George Gaylord Simpson; that, contrary to the adaptationist paradigm, adaptation is neither the only nor necessarily the most important force influencing traits; and that understanding in community ecology and in evolutionary lineages requires novel concepts appropriate to the level of analysis. These convictions jointly motivate the research program, outlined in the

present book, of "historical ecology" viewed as an integration of ecology, ethology, and phylogeny. The germane history of these disciplines is reviewed and the central distinction is introduced between microevolutionary processes occurring within species and macroevolution among species, the latter including transformational and taxic aspects emphasizing adaptation and speciation, respectively. The view put forward here, and invoked throughout the book, that these processes operate autonomously at different levels of a biological hierarchy, parallels similar arguments for the irreducibility of physiology to biochemistry, and social science to biology, and as such participates in one of the great and ongoing debates in science generally. An overview of the terminology (a polysyllabic edifice to be sure) and methodology of phylogenetic systematics (assumed a priori), including various "crimes against phylogenetics", answers Everything Your Ever Wanted to Know about Hennigian Techniques.

The focus then turns to phylogeny and the evolution of diversity through speciation and adaptation. Under speciation, appropriate attention is paid to modes of speciation (especially sympatric speciation which requires special circumstances which are nonetheless found in certain groups of organisms), the frequencies of these modes, and mirco- and macroevolutionary processes (such as isolation mechanisms and relict species, respectively). The origin, diversification, and maintenance of adaptations are considered from a phylogenetic perspective in terms of methodological caveats, temporal sequences, and coadapted traits. This perspective is shown to clarify matters such as convergence and divergence, and the several senses of adaptive radiation.

The relation of phylogeny and the evolution of ecological associations raises the nature of interspecific interactions, coevolution by descent and by colonization, and proper units (species and associations) for micro- and macroevolutionary analysis. For the study of cospeciation, cladograms, indication geographical arrangements, are introduced as parallels to phylogenetic trees, and methodological problems, such as the ambiguous interpretations made possible by widespread taxa, are outlined. The role of host switching and the issue of congruence between cladogram and phylogenetic tree as evidence for cospeciation are highlighted. Coadaptation can be viewed as the product of allopatric cospeciation, resource tracking, and evolutionary arms races, although the relative frequencies of these modes cannot at present be established. Evolutionary specialization involves resource specificity and genetic diversity, and communities are influenced by many historical and ecological factors. A concluding prospective urges that historical ecology is a feasible and relevant program which can contribute in such areas as conservation, functional morphology, and experimental and statistical approaches. Less compelling are the putative distinct ecological and geneological hierarchies seen as underpinning evolutionary phenomena.

The presentation is discursive, even fulsome, and, perhaps inevitably, occasionally redundant. The strength of the book is the synthesis of diverse material from ecology, ethology, and systematics into a vigorous intellectual framework for innovative studies. The five biologists to whom this volume is dedicated would no doubt be impressed with the great use of their contributions and simultaneously with the complexity of the contemporary endeavor. Support for this central core of arguments is sought in an almost overwhelming number of case studies, including, not surprisingly, much work by the authors, presented in great detail, with accompanying data matrices and diagrams. (A striking example is how the helminth parasites of certain Amazonian stingrays indicate a Pacific origin for this group.) Persistent major problems, such as the meaning of "species" and "community", are justly prominent. For many readers the level of detail of what is included may be more than desired, while the lack of discussion of key assumptions may be less, but there is certainly no lack of material here for reflection.

PATRICK W. COLGAN

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Grizzly Cub: Five Years in the Life of a Bear

By Rick McIntyre. 1990. Alaska Northwest Books. (GTE Discovery, Bothell, Washington). 104 pp., illus. U.S. $14.95; $18.95 in Canada.

This is a nice little book. It is set in Denali National Park and Preserve, Alaska, where author McIntyre served as a Park Warden for a number of summers. The book describes five summers in the life of a Grizzly Bear; McIntyre observed and photographed a Grizzly Bear cub, from his first spring to his untimely death in the fall of his fifth year.

The author recounts the cub's relationship with his mother, describes how he related to the environment around him, and provides insight into his behaviour towards people. It is an easy read, and is punctuated with biological facts about the Grizzly Bear. In addition to the main text, there is a short piece on what to do when encountering a Grizzly Bear in its natural habitat.

The book has a sense of sad reality to it. This bear developed a taste for garbage at an early age, and in

the course of searching for human food, scavenged in local dumps and ransacked some buildings. McIntyre describes the efforts of Park Wardens to deter the bear with non-lethal rubber bullets and cracker shells, and to condition it to avoid people. Unfortunately, their efforts were not entirely successful, and during an attempt to relocate the bear to new habitat, it died.

The photographs are the strength of this book; although they concentrate on the cub and his mother, they provide the reader with an appreciation of this beautiful Alaskan Park and Preserve. The book is a little expensive, a result of the high quality paper from which the author's photographs leap out at you.

It is an excellent book for children, people learning about Grizzly Bears, or readers who appreciate fine photographs. The only complaint I have is that a map showing the location of Denali National Park and Preserve is missing — something important for learning readers.

PAUL A. GRAY

Wildlife Policy Branch, Ontario Ministry of Natural Resources, P.O. Box 7000, Peterborough, Ontario K9J 8M5

The Jackson Hole Elk Herd: Intensive Wildlife Management in North America

By Mark S. Boyce. 1990. Cambridge University Press, New York. 306 pp., illus. U.S. $75.

Mark Boyce is a professor of Zoology at the University of Wyoming and has spent years studying the Jackson Hole Elk Herd which winters near Jackson, Wyoming adjacent to Grand Teton National Park. Management of this herd of more than 10 000 Elk has been, and continues to be, controversial and demonstrates the problems created by inadequate attention to habitat acquisition and appropriate management of human activities be that hunting, logging, livestock grazing, subdivision, or oil exploration. Instead of aggressively purchasing winter range in the Jackson Hole area years ago, the state of Wyoming chose to begin a winter feeding program. The program is both expensive and creates its own problems such as disease transmission, as well as artificially high concentrations of animals in relatively small areas. Boyce believes that the benefits associated with continued feeding outweigh the costs, although he admits that this solution is still less desirable than having a wild, free-roaming, self-sufficient Elk population.

The book's focus is clearly on the Jackson Elk herd. Boyce discussed the pros and cons of winter feeding, conflicts between other lands uses such as livestock grazing, hunter management, and the controversial hunting of Elk in Grand Teton National Park — one of the few national parks in the world where hunting is permitted. The book details how Elk numbers are fine-tuned and managed to maximize both hunter opportunity and wildlife viewing opportunities. Readers interested in a general text on Elk behaviour or ecology might find some of the chapters somewhat tedious and too specific to the Jackson herd to be of use as an overview of Elk biology. However, for those willing to read quickly through the Jackson Hole specific information, there is much of value in this book that has applicability to Elk throughout their range. Overall I found Boyce's book to be a well balanced discussion full of carefully documented information and insights into the management of one of North America's great wildlife assets.

But perhaps the most powerful reason for reading the book from my perspective has to do with what management of the Jackson Hole Elk herd represents and what it may portend for the future of wildlife everywhere if we are not careful. In reality management of the Jackson Hole Elk herd does not differ significantly from livestock ranching and the consequences are a domestication of Elk and the landscape in which they live, and to my mind, a loss in the "wild" part of the word wildlife. If management of the Jackson Hole Elk herd represents the best we can do, then it is not good enough for me, and a more visionary approach to both land and wildlife preservation is essential if we are to truly keep our wildlife "wild".

GEORGE WUERTHNER

Box 273, Livingston, Montana 59047

The Natural History of the Wild Cats

By Andrew Kitchener. 1991. Comstock Publishing Associates/Cornell University Press, Ithaca, New York. xxi + 280 pp., illus. + plates. U.S. $27.50.

In the Series Editor's foreword, Ernest Neal states that this series of books aims to bring available information together in an exciting and readable format so that all who are interested in wildlife may benefit from such a synthesis. He also states that the intention of this series is to go beyond the limits of other recent natural history books by explôring the subject in greater depth and by making available the results of recent research. Kitchener, Curator of Mammals and Birds at the Royal Museum of Scotland in Edinborough, has done an exceptional job in fulfilling these formidable standards.

The book contains eight chapters including discussions of felid adaptations for hunting and procuring prey; evolutionary relationships between extant and fossil species; brief species accounts including physical appearance, habitat preferences, and distribution; hunting, killing, and feeding behaviour including predator/prey relationships and interspecific competition; an excellent synopsis of representative food habits studies; social organization; reproductive behavior and life histories; and cat/human relationships. What is so appealing about Kitchener's book is the practical synthesis he employed in the use of available information on Felidae as compared to the species by species accounts that are more commonly used but often redundant and less informative. Following these chapters is a very useful appendix listing published (and unpublished [*Felis wiedii*]) body weights and measurements of wild cats categorized by lineage and geographic area. Kitchener notes that the food habits of wild cat species are often the most studied and well known aspect of their ecology. As such, he frequently states areas of their ecology in need of more detailed study and clarification.

The bibliography is quite exhaustive and current relative to the publishing date of the book. However, I was surprised to note that several classic monographic treatments of certain species were not referenced (e.g., S. P. Young and E. A. Goldman. 1946. *The puma, mysterious American cat.* Stackpole Company, Harrisburg, Pennsylvania. 358 pages, and S. P. Young. 1958. *The bobcat of North America.* Stackpole Company, Harrisburg, Pennsylvania. 193 pages). Nonetheless, it will prove to be an invaluable reference for those interested in pursuing a more detailed understanding of these carnivores. The index is functional and relatively complete although, because of potential confusion over common names of wild cats, it would have been appropriate to include scientific names as major headings with references to the common names also used in the index. The color plates and illustrations are overall quite good, adequately suited for their intended purposes.

I found only one typographical error. There is also a problem with the structure of the last sentence beginning on page 74. Additionally, there are inconsistencies in the tense used in portions of the text. As the author's intent was to emphasize summarization of previous information on the smaller cats, it would have been appropriate to have at least included a color plate of all 37 or so species (if available). However, these errors, oversights, and omissions are minimal and in no way detract from the exceptional quality of the book.

Overall, I believe that this book is a valuable contribution to literature on the Felidae. I highly recommend this reasonably priced book without reservation to anyone with an interest in this very specialized group of carnivores.

JERROLD L. BELANT

U.S. Department of Agriculture, Denver Wildlife Research Centre, 6100 Columbus Avenue, Sandusky, Ohio 448770

Frozen Fauna of the Mammoth Steppe: The Story of Blue Babe

By R. Dale Guthrie. 1990. The University of Chicago Press, Chicago. xi + 323 pp., illus. Cloth U.S. $40; paper U.S. $16.95

One of the great excitements for palaeontologists is being able to apply field data from studies of modern fauna and flora to situations in the palaeontological record. Guthrie's *Frozen Fauna of the Mammoth Steppe* is a shining example of this process. Guthrie's years of living and studying in Alaska, along with his studies on the African savannas and in the Soviet Union, provided the living analogies he applies in piecing together the story of Blue Babe, a 36 000-year-old Alaskan steppe bison, and his environment. Blue Babe, named for Paul Bunyan's legendary companion, is a remarkably well-preserved partly-consumed bison carcass found in an Alaskan creek bank during placer gold mining in 1979. Guthrie rescued the remains and spent much of the next few years unravelling Blue Babe's life and death. This book is a record of that investigation and a fascinating account of the process of research.

Guthrie proposes, and disposes of, a series of hypotheses that might account for Blue Babe's death. He finally accepts, albeit with a curious air of resignation, that the death resulted from an attack by Pleistocene lions. In support, he presents a series of

physical attributes of the carcass (claw marks in strategic positions on the hide; patterns of tooth marks on the snout; the systematic though incomplete consumption of the carcass) and demonstrates, by analogy to the killing behaviour of African lions, that two or three Pleistocene lions killed Blue Babe. Paired fang punctures on the bison's facial area average 8.5 cm apart, a value that eliminates all other contemporary carnivores because their jaws were much narrower. Guthrie also explains the differences in function and effect of the stabbing canine teeth of both lions and sabre-toothed cats as further evidence of lion predation.

Guthrie draws extensively on his studies of modern bison to reconstruct Blue Babe's appearance when alive, supplementing biological inferences by analysis of drawings of steppe bison made by Paleolithic artists. As a corollary to this, he builds comprehensive hypotheses about *Bison priscus*, Blue Babe's species, that describe herd size, herd composition, coat colour, male combat strategies, and seasonal segregation of males and females, because these all would have differed from those of modern plains bison (*Bison bison*).

While concentrating on Blue Babe, Guthrie does not neglect the environment in which he lived. He reasons that Blue Babe lived in a predominantly grassland landscape that existed in unglaciated Beringia during the Late Pleistocene, particularly during glacial episodes elsewhere. In support, Guthrie cites evidence from vegetation remains in feces and stomach contents of other mummified carcasses from the north, plant fragments found in bison teeth, wear patterns on fossil bison teeth, and a knowledge of the animals' dietary strategies. This scenario is rooted firmly in biology and palaeontology. Against this, Guthrie discusses evidence from other researchers, derived mainly from palynology, that large areas of Beringia were polar deserts or sparsely-vegetated tundra during glacial intervals, incapable of supporting fauna in the numbers and diversity that he envisages. This debate over the existence of the "Mammoth Steppe" has been ongoing for years. Guthrie argues his point of view well when discussing the faunal evidence. In places, however, his analysis of pollen data is unclear and is obscured by confusion in text and diagrams between pollen concentration (grains/cm^3) and pollen influx (grains/cm^2/yr) values. Some observers have viewed the Beringian landscape as a mosaic, accepting that elements of both explanations may be true for different areas. Guthrie rejects this compromise.

This book is an outpouring, almost autobiographical, as it draws on Guthrie's personal experiences and builds on a published record of academic accomplishments spanning twenty-five years. The breadth of material covered is impressive. Among many other topics, besides bison biology, Guthrie surveys the history of the study of similar preserved carcasses beginning in the early nineteenth century, geomorphological processes leading to the burial and preservation of the remains, and hunting strategies of prehistoric people. It is an exciting and entertaining volume, filled with enthusiastic and incisive arguments. Other reviewers have played up the "detective story" aspect of the book and, indeed, it has that in abundance, and perhaps that above all is what makes it such compelling reading. In addition, Guthrie's use of pen and ink drawings to convey points of discussion is very effective, because photographs often fail to bring out pertinent details clearly.

Shortcomings it has. The editing is uncharacteristic for the University of Chicago Press. Typographical mistakes and bad spelling, some poor grammar, occasional inconsistencies, and an error-laden list of cited references mar the product. In places, the discussion becomes quite technical; a glossary would have been helpful. These problems, however , are not sufficient to detract from the overall superior quality of this book.

Guthrie's book is an engrossing and captivating read. From it, readers will begin to gain insight into the attractions and excitement of palaeontology. For naturalists, the book highlights the value of patient observation of living organisms and their interrelationships with their environment. Guthrie shows how careful analysis and intelligent deliberation can build up a comprehensive picture of long-vanished animals and their landscapes. Listen up: you can almost hear Blue Babe snorting down your neck!

JAMES A. BURNS AND ALWYNNE B. BEAUDOIN

Provincial Museum of Alberta, 12845-102nd Avenue, Edmonton, Alberta T5N 0M6

Wild Echos: Encounters with the Most Endangered Animals in North America

By Charles Bergman. 1991. Alaska Northwest Books, GTE Discovery, Bothwell, Washington. 324 pp., illus. U.S. $12.95; $15.95.

Many articles and books have been written on endangered animals as a topic. Bergman however, in his book *Wild Echos*, highlights ten individual species and shares with the reader his personal encounters as well as detailed information about their history and current status.

The author hiked through swamps, went diving, flew across select terrain, and stalked the night forests for a glimpse of the animals he profiles. From

monitoring the last wild breeding pair of California Condors to aiding in the administering of vitamins to panthers (*Felis concolor coryi*) in Florida, the author writes of his experiences while accompanying trained personnel in the field in an ongoing and desperate attempt to ensure the survival of a species.

The author expertly conveys his feelings to the reader allowing one to vicariously experience the excitement of being in close proximity to these beautiful and often elusive creatures. He writes with empathic conviction a thought-provoking text encouraging readers to reflect not only on the natural world around us but more importantly, our relationship within it.

Throughout the text topics relating to the causes of certain species becoming endangered or extinct, including a major one, loss of habitat, are examined in detail. Accompanying Bergman's text on his excursions is an abundance of information relating to each particular species. Bergman attempts to shed some light as well on controversial issues like captive breeding and intensive wildlife management. The book concludes with a partial, but nonetheless extensive, list of extinctions as well as a listing of organizations concerned with wildlife the reader may wish to contact.

An unusual, but interesting addition worth noting in a book of this type is Bergman's inclusion of numerous references to, and quotes from literary works relating to the topic under discussion. Passages from *A Midsummer Night's Dream*, poetry by D. H. Lawrence, and quotes from other authors are inserted throughout the text. As Bergman is a Professor of English this appears to be a demonstration of his own unique approach.

Of the ten species Bergman highlights, the tragedy is the Dusty Seaside Sparrow which has been considered extinct since 1989 and a sighting of the Ivory-billed Woodpecker has not been documented in recent years. *Wild Echos* however, is a well-presented cry for the preservation and celebration of all the species that remain. Bergman has written an enjoyable, easily comprehended and informative book on a few of the many endangered animals in North America that serves to promote awareness and make one conscious of the true vulnerability of all life.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario KOA 2WO

Golden-crowned Kinglets: Treetop Nesters of the North Woods

By Robert Galati. 1991. Iowa State University Press, Ames. xi + 142 pp., illus. U.S. $18.95.

Until recently, the basic facts of Golden-crowned Kinglet reproduction were not well known. In my copy of the *Audubon Society Encyclopedia of North American Birds* (J. K. Terres. 1980. Alfred A. Knopf, New York), several entries, such as length of incubation period and age at fledging, are simply described as "unknown". Undoubtedly, the diminutive size of this bird and its habit of nesting near the top of tall trees are responsible for this state of affairs.

This lack of knowledge was corrected in 1985 by the publication of an article by R. Galati and C. B. Galati (1985, *Journal of Field Ornithology* 56: 28–40). The authors had observed, in 1954–1960, the reproductive efforts of 13 kinglet pairs in Itasca State Park, Northwestern Minnesota. Now, Robert Galati has published a book that intends to be a more personalized account of his and his wife's observations.

The first chapter, entitled "How we got started", is the most interesting. In it we learn of how the Galatis managed to find the nests of this elusive bird (essentially by climbing many trees!) and then observe the parents' behaviour from platforms erected in the nest tree itself or atop towers as tall as 16 m. Certainly the vagaries of working at treetop level are not usually described in technical reports. We are also told of the incredible tameness of kinglets. How many researchers can boast of being able to study feeding habits by simply removing prey items directly from the bill of the parents at the nest? How many ornithologists have taken the trouble to build a blind only to find the study bird enter the blind and perch on the observer's shoulders?

The other chapters cover, in order, the study location, vocalizations, territorial behaviour, the nest, eggs, incubation, nestlings and their development, fledging, experiments, and nesting success. The encyclopedic nature of some of the information is worthy (incubation lasts 15 days, young fledge 16–19 days after hatching) but unfortunately this and other more trivial findings are not presented within any conceptual framework. This makes for rather dry reading in places. Despite the author's best intentions, I found interesting anecdotes to be few and far between. Somehow, the field work feeling (excitement and tediousness alike) does not show through as it did in the first chapter. Could one blame this on the fact that the book was presumably written several decades after the actual study took place?

The book is small and well-produced. Twenty-seven black-and-white photographs accompany the text. Nine line drawings by Colleen Helgeson Nelson show the different stages of nesting development (one more drawing shows a pendulum-type nest). I think that this book will appeal to ornithologists interested in the natural history of Golden-crowned Kinglet reproduction (although I would advise them to first consult, as a cheaper alternative, the Galatis' 1985 article in the scientific literature) and to people who have done similar observational work on other species.

STÉPHAN REEBS

Département de Biologie, Université de Moncton, Moncton, New Brunswick E1A 3E9

"Language" and Intelligence in Monkeys and Apes: Comparative Developmental Perspectives

By Sue Taylor Parker and Kathleen Rita Gibson. Editors. 1990. Cambridge University Press, New York. xviii + 590 pp., illus. U.S. $65.

It is not surprising that throughout the entire history of the study of animal behaviour no area has generated more interest or controversy than the higher capacities of our nearest relatives. The present work reflects this continuing focus, with most chapters based on a workshop in 1986 but updated in the interim. The first of six groups of chapters establishes a theoretical framework. Parker provides a historical survey of germane portions of anthropology, ethology, primatology, and psychology. Within this a program of comparative developmental evolutionary psychology, mercifully acronymized to a CDEP, is proposed as an extension of Piagetian theory. While readers trained in the traditions of either behaviourism or the "modern synthesis" of biology will appropriately draw a deep and suspicious breath at this proposal, they need not panic: Piaget is invoked only in some of the subsequent chapters, and always critically, with due attention to the problems surrounding his legacy. On another front, the use of heterochrony here as in behavioural ecology reflects the increasing attention paid to this concept. In the first of two chapters addressing neural substrates, Parker interestingly considers, in the context of the theory of life histories, how intelligence in primates is likely constrained by the high metabolic costs of large brains. Within an examination of the relations of brain size and behavioural skills, Gibson argues against the conclusion that human intelligence is achieved through neonatal altriciality. In a fourth chapter Parker and Bernard Baars review the multiple uses of key terms, a litany which may be useful and is certainly tedious.

Three of four chapters on cebus intelligence adopt Piagetian approaches (one reporting on a single individual of uncertain ontogeny and species!). The fourth, and most intriguing, by Dorothy Fragaszy, analyzes sensorimotor development in capuchins in terms of dynamical systems and time series, with different activities at different developmental stages viewed as attractor stages. Among three chapters in imitation and cultural transmission, the two informative ones both issue cautions on views which are presently widely held: Elisabetta Visalberghi and Fragaszy conclude that in monkeys imitation plays at most a limited role in behavioural acquisition while Michael Tomasello shows that to the extent that chimpanzees have cultural transmission, it is very different from our own.

Among four chapters on social intelligence and communication in great apes, there are noteworthy similarities in the use of communication to solve problems in the gorilla studied by Juan Dómez and the orangutans by Kim Bard. Among three chapters on numerical and classificatory abilities, Tetsuro Matsuzawa profitably compares spontaneous sorting in a chimpanzee with young children while Irene Pepperberg does likewise for conceptualization by her African grey parrot with chimpanzees. In two final chapters on linguistic ontogeny in apes, Lyn Miles reports on the acquisition by an orangutan of some 140 signs based on American Sign Language, while Patricia Greenfield and Sue Savage-Rumbaugh, on the contentious question of grammatical use by apes, carefully demonstrate that bonobos use and invent simple grammatical rules in patterns similar to both deaf and hearing children.

Among the reviews of previously published work and the fresh data provided here, there is much material for consideration, especially comparisons across species. Venerable concepts, especially genetic ones such as the "innate schoolmarm" of Konrad Lorenz, and such as parallels between ontogeny and phylogeny, the non-identity of intelligence and associative learning, and whether the occurrence of a new word is regarded as a lexical innovation or ambiguity, receive novel examination. Those who suspect that investigators studying fewer individuals become more deeply involved with them will be interested to know that of the 14 chapters presenting new data, the three longest deal with a total of four subjects (two individuals and one pair). (Presumably if communication with some of these subjects progresses, they will be promoted from named entries in the text and index to the status of co-authors.) Given the known wide individual variation among primates, as acknowledged by some of the authors, the signifi-

cance of these reports must be viewed skeptically. This book is no beginner's guide, but is a good overview of the state of the discipline. Its chief contribution is its addition to the impressive array of evidence concluding a major controversy of enormous historical importance: that the differences between humans and our relatives are in degree, not kind, a conclusion which should humble us and protect them.

PATRICK W. COLGAN

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

Pacific Salmon Life Histories

By C. Groot and L. Margolis. 1991. University of British Columbia Press, Vancouver, British Columbia. xv + 564 pp., illus. $65.

Pacific Salmon Life Histories is an attractive volume which deals with species of the genus *Oncorhynchus*. The book is nicely bound and the layout of the text in two columns is appealing. The print is large, clear, easy to read and there are very few typographical errors.

Each species description is complemented with a coloured reproduction of a painting by H. Heine showing the life history stages. There are also colour photographs, numerous maps, graphs, and diagrams to support the text. Many tables summarize data on lengths, weights, ages, and other life history parameters.

A brief preface introduces the seven species of Pacific salmon and comments on their importance as commercial, recreational, and subsistence fishes. *Salmo* species are excluded from the book because they are considered to be trout. The different systems used for recording salmon ages are outlined.

The preface is followed by five reviews, each by a different author, describing Sockeye Salmon, *O. nerka* (R. L. Burgner), Pink Salmon, *O. gorbuscha* (W. R. Heard), Chum Salmon, *O. keta* (E. O. Salo), Chinook Salmon, *O. tshawytscha* (M. C. Healey) and Coho Salmon, *O. kisutch* (F. K. Sandercock). These species are distributed on both the Asian and North American coasts of the North Pacific ocean. A sixth review by F. Kato deals with the Masu and Amago salmons, *O. masou* and *O. rhodurus*, found only around the Japan and Okhotsk seas. The book ends with a geographical index giving the location and coordinates of the many place names in the text and a subject index.

Each review follows a similar format, perhaps agreed upon during the planning of the volume. Each stands on its own as an independent contribution. The topics covered are: distribution of spawning stocks, abundance and importance, spawning migration, nest selection, spawning, fecundity, incubation, emergence, fry dispersal, freshwater life (if applicable), early sea life, offshore movements and ocean distribution, diets, age and growth, morality patterns and abundance, harvest, and harvest trends. Each review ends with a concluding remarks section which overviews the present status of the stock of each species. The focus of each review is the natural range in the North Pacific but where transplants have been made outside this area these are briefly mentioned. Each review is supported by an extensive bibliography, the number of entries reflecting the abundance and importance of the species. The oldest reference is to a work published in 1792 and twenty-three percent are pre 1960, a period when basic life histories were first being studied. The balance of the citations are spread over the last 30 years, with peaks towards the end of the 1960s and between 1978 and 1984. There are few references after 1987. The references provide an excellent entry into the literature and it was particularly pleasing to see a good coverage of the Russian literature.

The authors of each review are acknowledged experts. All are active researchers who have contributed to the literature on the species they review. Their knowledge and understanding of the life histories they write about has enabled them to produce accurate, authoritative, and thoughtful reviews. The editors are to be complemented on the choice of authors and their skill in combining their different writing styles into an even and balanced synthesis. Although the formats of each are similar, the approaches and treatment of the topics are surprisingly different, reflecting the authors' interests and experience, as well as differences in the depth of knowledge about different topics between species.

My complaints about the book are minor. I found some of the page breaks distracting, the worst being on page 501 where two lines get squeezed in above the figure and seem quite out of place. Several of the figures in section one in my review copy were pasted in, which detracted a little from the appearance. My criticisms are few. It is a pity that the most recent reference on Masu and Amago salmon was 1985. Thus papers that appeared in the Proceedings of the International Symposium on Charrs and Masu Salmon, in Sapporo, Japan in 1988 (Spec. Vol, Physiology and Ecology, Japan, December 1989) were missed. I was also sorry that a comparative overview of the Pacific salmons had not been attempted by the editors. I think it would have been a useful summary at the end of the book. Suitable

themes might have been sharing the environment by the different species or human impact on the species by fishing and by changes to the freshwater habitat. Each section contains some of this discussion, but it is left to the readers to pull it together for themselves, if they so desire. Something on future directions might also have been appropriate in view of the impact aquaculture is (or might be) having on the Pacific salmons and in view of the salmon enhancement efforts in many countries. Perhaps the book would then have become too large.

For anyone wanting an easy and good introduction to the biology of any of the *Oncorhynchus* species, this book is an obvious place to start. The book should find a place on many book shelves, not just in specialist libraries around the North Pacific. I recommend it to anyone with more than just a passing interest in salmonid fishes. It was intended to serve a broad audience of students, teachers and the general public as well as be useful to fisheries professionals and I think it succeeds admirably.

G. POWER

Department of Biology, University of Waterloo, Waterloo, Ontario N2L 3G1

Immature Insects, Volume 2

By Frederick W. Stehr, Editor. 1991. Kendall/Hunt, Dubuque, Iowa. xvi + 975 pp., illus. U.S. $215.

Three years ago I reviewed the first volume of *Immature Insects* (*Canadian Field-Naturalist* 1989, 103(2): 304–305). I gave that volume a strong recommendation and several years of use have not dampened my enthusiasm for it. Now, after a long delay, comes the second volume, which treats the 10 orders not covered in Volume 1. These are the Thysanura, Hemiptera, Homoptera, Megaloptera, Raphidoptera, Neuroptera, Coleoptera, Strepsiptera, Siphonaptera, and Diptera. Over half of the book, 515 pages, is devoted to Coleoptera, the largest order of insects. Almost half of the remaining pages are devoted to Diptera. There is also a very brief introduction, a glossary of technical terms, a host and substrate index, and a taxonomic index. Finally, there is a one page list of "Corrections, Additions and Modifications for Volume 1."

The second volume is laid out in the same style as the first. Each treatment of an order begins with an introduction, a detailed account of larval morphology or a diagnosis, some discussion of biology and life history, and a presentation of the systematics of the order as presented in this work. These sections are followed by a key to the families and detailed, often diagnostic, treatments of the families. In most chapters, only the families of North America north of Mexico are included. However, the chapters on Coleoptera and Strepsiptera are worldwide in scope, the chapter on Megaloptera keys larvae to the generic level, and the chapter on Strepsiptera includes a key to adults as well as a key to primary larvae. Within the Coleoptera and Diptera, selected families are treated at the subfamily, tribe or generic levels, and in a few instances, selected species are keyed. There is no apparent rationale for the selection of groups for more detailed treatment. In the Diptera, for instance, the Asilidae are keyed to subfamily, and selected common *Delia* root maggots (Anthomyiidae) and the three most common *Gasterophilus* bot flies (Gasterophilidae) are keyed to species. A similarly limited selection of families receives detailed treatment at subfamily, tribe, generic, or species level among the Coleoptera. This uneven treatment is puzzling, but is probably the result of producing a volume having 46 contributing authors. There are similar treatments of selected groups below the family level in Volume 1, as well, but the selections there seem less odd. Each chapter is well illustrated with numerous, generally excellent line drawings. There also are many fine scanning electron microscope photographs in the chapter on Coleoptera.

This is a remarkable book and an essential addition to the first volume. Professional entomologists who work with immatures need both. Unfortunately the price will severely restrict the market. "There were reasons," according to a sales representative at Kendall/Hunt, for the $215 price tag for volume 2. Obviously, the set ($69.95 for Volume 1; $215.00 for Volume 2) cannot be a required purchase of students in an entomology course. Other than a few independently wealthy entomologists (an oxymoron?), only libraries at major universities and perhaps a few instructors who have it in their course budgets are likely to buy a copy. And that is a shame, because this two volume set deserves a place on the shelves of entomologists and biologists everywhere.

CHARLES R. PARKER

Uplands Field Research Laboratory, Great Smoky Mountains National Park, 1314 Cherokee Orchard Road, Gatlinburg, Tennessee 37738

A Guide to the Birds of Nepal

By Carol and Tim Inskipp. 1991. Second edition. Smithsonian Institution Press, Washington. 400pp., illus.

Although it is only about the size of England and Wales, Nepal has a rich avifauna, a fragile economy, and a big heart: nearly 10% of the country is set aside for conservation. Since the 1985 first edition, a substantial amount of new ornithological information has become available. This edition incorporates 3000 new distribution records and some species name changes. It is not a field guide, but a comprehensive (834 species) breeding and distribution bird atlas. It is an achievement to have collected the data in an area where altitudes range from 75 to 9000 metres, and where access is so difficult.

For every species listed there is a black-and-white drawing, a history of sightings (or "collectings"), a grid map, and small horizontal bars showing the altitude levels of the bird's range and the months of the year it is resident. Each sighting record is cross-indexed by number to the bibliography, which contains over 800 references. The 8 colour plates are of the warblers, rosefinches, and buntings, whose subtle differences can only be shown in colour. The *History of Ornithology in Nepal* is one of the introductory chapters. Ornithology in Nepal made a good start when Brian Hodgson became British Resident in Nepal in 1820. In 23 years he recorded 665 species of birds, and collected 9500 skins, which he shipped to London. These are still available for study. Other chapters cover topography, climate, and vegetation; conservation of habitat (the authors intend the study as a basis for future conservation plans); and migration, particularly over the Himalaya, on which there has been little research so far. Travel routes are described: some sites can be reached by local bus or taxi from Katmandu. A particularly useful section for birdwatchers, since it covers birds found across Asia, illustrates and describes "confusing species" such as accipiters, falcons, pipits, owls, and buntings. This is certainly not a superficial study. Ornithologists of all shades who are looking for information on global bird populations, and travellers to Nepal or north-east India who want a broader perspective than a field guide offers, will find this book invaluable.

JANE E. ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T6

Harp Seal, Man, and Ice

By David E. Sergeant. 1991. Canadian Special Publication of Fisheries and Aquatic Sciences 114. Fisheries and Oceans Canada, Ottawa. xi + 153 pp., illus. $28.50 plus shipping.

In recent years public attention has increasingly focused on culling programs and fisheries for seals. Public pressure has generally resulted in the decline in many of these culling operations and fisheries. Whether "perceived" or real, conflicts between seals and fisheries are emphasized by those in favour of the reimplementation or expansion of seal fisheries and/or culling programs. One thing lacking in many (if not all) cases is the availability of scientific information to base management decisions on. In the case of Harp Seals in the North Atlantic, possibly the second most abundant seal worldwide, Sergeant provides a thorough review of much of the available data and scientific opinions on this species. Also presented in this volume is considerable original information and previously unpublished data on Harp Seals.

This information has been collected by the author over his long career studying this and other species of marine mammals in the North Atlantic and Canadian Arctic. With the plethora of "coffee table" books on wildlife flooding the current book markets, such a scientific treatment is refreshing. The twelve chapters extensively review the animal's biology and natural history. However it is clear that much remains unknown about the population size, trends, feeding habits, and numerous other aspects of the biology and natural history of this species, despite intensive research over many years.

From a technical standpoint, although thoroughly illustrated, many of the illustration captions are insufficient to adequately explain their contents. Many are reproduced from their original scientific sources and thus may contain detailed information that is not relevant to their treatment in this book. In several figure captions, references to pages in the text were left blank when the final layout was being proofed, making it difficult to refer to the appropriate sections.

The last several chapters deal with the value of Harp Seals to man, the potential effects of pollution, and prospects for the future use of this species by humans. However, conservation concerns get little attention and the bias of the author regarding continuing Harp Seal fisheries in the Atlantic provinces of Canada is clear.

The volume does have a detailed bibliography and an index providing references to original sources and easy access to particular subjects within the volume. However, an appendix on female reproductive rates

in the Gulf of St. Lawrence requires considerable review to determine its use or value. The volume closes with a page of recipes using harp seal meat, which some may find interesting, but which seems somewhat out of place.

This book appears to be designed primarily for the scientist or for those seriously interested in the Harp Seal or other marine mammals. At its low cost it is worth purchasing and it is likely to be well distributed and read.

ROBIN W. BAIRD

Marine Mammal Research Group, Box 6244, Victoria, British Columbia V8P 5L5

Moosebirds and Sandpeeps: Birds in and Around Fundy National Park

By David Christie. 1991. The Fundy Guild, Box 150 Alma, New Brunswick E03 1B0. 33 pp., illus., $3.95 plus postage.

David Christie is one of those pleasant people you keep running into as a bird watcher. His friendly approach comes through in this booklet on the birds in Fundy National Park and nearby areas such as Shepody Bay. Although some of the material is standard to any field guide (the song of the Ovenbird, for example), the site specific information is most valuable. This is where the booklet scores. The directions on what, where, and when to find birds will assist new local birders, visiting enthusiasts, and general naturalists. David also gives a summary of the region's various ecologies, which explains why the birds are found where they are. The back cover is a cleverly designed bar chart of abundance and seasonality of 87% of the birds that have occurred in this region.

For the price I can give you four good reasons to buy this attractive booklet. First, you will enjoy the ecological insights in Christie's notes (Do Semipalms really eat that many mud shrimp a day?). Second, it will whet your appetite to visit one of Canada's best birding spots (I missed the peak last time. I only saw 60 000 sandpeeps in one flock!). Third, your purchase will support the Fundy Guild and perhaps encourage Christie to write more. Finally, if you plan a trip to Fundy National Park this booklet is essential.

ROY JOHN

544 Ketch Harbour Road, Box 13, Site 2, RR #5, Armdale, Nova Scotia B3L 4J5

The Traveling Birder: 20 Five-star Birding Vacations

By Clive Goodwin. 1991. Doubleday, New York. 306 pp., illus. U.S. $13.

Clive Goodwin has set on paper what most of us only do vocally; tell stories of our favourite birding trips. Like all tales told by the campfire this book varies in level of detail and depth. Whole countries, like Kenya and England, are given hardly more space than specific localities like Point Pelee or Churchill. Many reminiscences, too, are coloured by the success or lack of it that the individual achieved rather than the place's potential. With this in mind you will probably go through the same type of emotional roller coaster as I did, but not necessarily in the same places or for the same reason.

There were places where I agreed with Clive and it was exciting to relive a shared experience. His visit to Newfoundland brought back good memories of being inundated with Puffins, Gannets, and other seabirds. (Although I missed the Black-browed Albatross. I was on the ferry a day too early!) The chapter on England and Wales is quite spartan for a visitor, barely touching on the highlights, but for me it recaptured many wonderful experiences.

There are points to disagree with too. For me Clive's account of Point Pelee describes the way it used to be. Us oldtimers can well remember the real flood of birds that hit the Point each spring, a sight we shared with but a few hundred enthusiasts. Pelee still gets the heart-stopping rarities and many other good birds, but the numbers are gone and the sheer volume of visitors has taken away much of the "wilderness" experience of a Pelee spring. My strongest disagreement, though, is in Clive's choice of Maine as one of his top twenty. I do not feel I am being prejudiced in suggesting the Canadian maritimes as a better choice. Fundy National Park, Shepody Bay, or the south and eastern shores of Nova Scotia have much more to offer. Wide sandy beaches still have Piping Plover, boreal forests can be searched for jays, grouse, crossbills, and chickadees. And seashore marshes with their ducks and shorebirds are wilder and more appealing than in Maine.

Clive also whets the appetite for places as-yet-unvisited. My twice-planned and twice-cancelled trip to southern Spain has been given new life by his account. Kenya is a little more long-term objective.

On the practical side, the author provides useful hints on bird and bird-finding guides, travel and accomodation, and other thing to do in the area. (I thought that this author was going to be the first to

write about Spain without mentioning Sherry. But he squeezes in the briefest of mentions in the last half of the last sentence in the book!). Most of the non-birding information is in boxes within the text. This means you can read the interesting part without distraction, but the important travel material is still easy to find.

Any avid birder will enjoy reading this book; comparing, as I have done, with their own personal experience. This is an ideal book for a gift to that birder who already owns all the field guides and where-to-find books. The recipient will have fun. But please do not borrow the book, buy it. Book sales will encourage Clive, and maybe others, to write more.

ROY JOHN

544 Ketch Harbour Road, Box 13, Site 2, RR #5, Armdale, Nova Scotia B3L 4J5

Waterbirds of the Strait of Georgia

By E.C. Campbell, R.W. Campbell, and R.T. McLaughlin. 1991. British Columbia Waterfowl Society, Delta, British Columbia. 60 pp., illus.

This booklet is a laudable attempt to provide a compact guide to finding and identifying birds around the Strait of Georgia. Generally speaking, it is aimed at the beginning birder or general naturalist level, but more experienced birders will find much of the information of use. The first third is taken up with concise but informative descriptions of the important areas around the Strait of Georgia where birds concentrate, either to nest (e.g., seabird colonies), pause during migration (e.g., the rich upwellings at Active Pass), or to spend the winter (e.g., wintering waterfowl of the Fraser River delta). Information is given on both well-known areas visited by thousands of birders annually such as Boundary Bay, as well as less frequented areas like Mitlenatch Island Nature Park. Twelve sites are described: Oak Bay, Mandarte Island, Active Pass, Boundary Bay, Fraser Delta, Howe Sound, Sunshine Coast, Northumberland Channel, Qualicum Beach, Baynes Sound, Comox Harbour, and Mitlenatch Island. The locations of each site are pointed out on maps of reasonable quality. For each site, a summary of birds present at different times of year is provided. The only weakness of this section is that little information is provided on how to get to the sites. For example, visitors to Vancouver will be excited to read about the spectacular concentrations of shorebirds and waterfowl at nearby Boundary Bay, but left wondering how to find the place and where the best spots to watch from are located.

The following section, which takes up most of the remainder of the book, contains species accounts for most of the common and uncommon waterbirds of this area. For each species two photographs are presented, showing male and female, or birds in winter and summer plumage if the sexes are alike. The quality of the photographs used (most by Ervio Sian) is uniformly excellent. Except for the winter-plumaged Red-throated and Pacific Loons, the photographs are correctly identified. The major field-marks for each species are summarized, and a chart shows the status (abundant, uncommon or rare) in each month of the year. The presentation is clear enough that novice naturalists will quickly be able to identify what they see without consulting a more detailed bird guide. The charts for all species are repeated later, and the populations at major seabird colonies are summarized in a separate appendix.

This booklet will be particularly valuable to birders visiting the Vancouver area. Even those very familiar with the identification of the local avifauna will find the information on birding areas around the Strait of Georgia extremely useful. A small point that may be important to some is that the booklet is sponsored by MacMillan Bloedel Limited, the forest products corporation that many would say is responsible for large-scale environmental destruction around the Strait of Georgia. The booklet is *not* printed on recycled paper. Political considerations aside, this is a very attractive and informative booklet that will be useful to local and visiting naturalists alike.

IAN L. JONES

Department of Zoology, University of Cambridge, Downing Street, Cambridge, CB2 3EJ UK

The Birds of Japan

By Mark A. Brazil. 1991. Smithsonian Institution Press, Washington. 466 pp., illus. U.S. $49.95.

The first Japanese bird book appeared in 818 AD and described hawks and falcons. Then, as now, most of the birds found in Japan were species common in the Palearctic and Oriental regions, with migrants from Australia and the Arctic appearing in their seasons. In the mid-19th century several Europeans listed and collected many species; among them were Temminck (of the Stint and others) and von Kittlitz (of Murrelets). But through the centuries the Japanese have studied their birds intensively, as the lengthy list of references in the bibliography shows. In order to compile these, the author had to master written Japanese, no small feat.

Birdwatching has recently become a popular pastime for the Japanese. They have replaced the foreigners who flocked to Japan in the 1960s and 1970s when much of south-east Asia was at war. The new craze is bound to add more species to the present total of 589.

The introductory chapters of this breeding bird atlas are exhaustingly detailed and describe the Japanese climate, history, habitats, geography, and conservation. The main content is detailed histories for all recorded species. Some of the information is repetitious and the histories could have been more succinct. The individual range maps are awkward to refer to as they are in a separate section. Since this is not a field guide there are very few illustrations — some black-and-white drawings, and six colour plates illustrating the 16 endemic species.

Visitors to Tokyo with limited time can learn about the sites close to the city. Those with more time should visit the southern islands, called collectively Ryukyu or Nansei Shoto Islands, and should take the ferries between the other major islands to see pelagics.

As has happened all over the world, marshes, bogs, and flood plains have been drained or developed so that there are very few left. What is perhaps less common is that the coastline has been artificially strengthened to halt erosion, and as a result many species associated with these habitats are not common.

The information in *The Birds of Japan* will be useful for western ornithologists of all levels. The dictionary of Japanese/English names and the addresses of bird societies will be valuable for visitors.

JANE E. ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T6

BOTANY

Rare Vascular Plants in Canada: Our Natural Heritage

By G.W. Argus and K.M. Pryer. 1990. Canadian Museum of Nature, Ottawa. 191 pp. + 85 pp. of maps. Paper $12.95 + $6. Shipping. Also available in French.

This publication represents the culmination of a project that began with provincial and territorial assessments of rare vascular plants well over a decade ago. The provincial and territorial lists serve as the primary references for the status of plants, and have been used extensively by government agencies, consultants, and field botanists. Not only have they stood as the "official" lists of rare plant species; they have also stimulated and directed renewed field activity. The logical extension of the rare plants program is the publication of this list of nationally rare plants.

Many species of vascular plants are rare in one or more of the jurisdictions in which they occur within Canada. However, some of these may be rare in one province, but common in the adjacent province. In order to qualify for inclusion in this publication, a taxon must be rare in *each* jurisdiction in which it occurs. This also implies that each taxon occurs in a relatively limited portion of each jurisdiction, and/or that its populations are relatively small. A total of 1009 taxa qualified for inclusion in this book (a little under one third of Canada's total flora).

Although various authors, with various concepts of rarity, contributed to the preparation of the provincial and territorial lists, the authors of this book feel that the nationally rare plants included here conform to "...a relatively uniform concept of rarity". From my perusal of the list, I must agree. Of course, there are a few species that perhaps could have been excluded if the criteria had been applied more rigorously. For example, American Ginseng (*Panax quinquefolius*) is known from a large number of stations throughout southern Ontario. However, because of the threat of extirpation from collectors for naturopathic and herbal markets, there is good reason to include it. The inclusion of several species of the Carolinian (southern deciduous forest) zone of southern Ontario could also be questioned (e.g., James' Sedge, *Carex jamesii*; Tulip-tree, *Liriodendron tulipifera*), since they are quite common within that restricted range.

This book provides a wealth of information about our nationally rare plants, in a very concise format. A series of introductory sections deal with reasons and causes of rarity, inclusion criteria, and explanations of The Nature Conservancy (TNC) ranking system and a novel Canadian priority rating scheme (intended to direct future efforts for the preparation of status reports and other conservation initiatives). The bulk of the book is composed of the species list. Each species is listed in alphabetical order, along with common synonyms, references, rankings (TNC, COSEWIC), and Canadian priority rating. TNC ranks are particularly useful, because they provide an indication of the level of rarity of each taxon in each province and territory (or District within the Northwest Territories) in which it occurs. In addition, all states in which the taxon is uncommon to rare are listed, with their TNC ranks. Thus, this book summarizes a lot of information that otherwise would have to be gleaned from numerous separate sources.

Following the species list, a series of appendices provides easy cross-referencing. The appendices include a list of species by family, a list of rare endemics, alphabetical lists for each province and territory, and lists by Canadian priority category. Thus, many jurisdictional conservation program needs can be served by one or more of these ready-made lists.

The book concludes with a set of range maps for the taxa included. Unfortunately, these maps are inadequate. They do not provide accurate reflections of the ranges of the species, because single dots are used to indicate occurrence within each jurisdiction. The dot is always located in the geographic center of the province, territory, or state. Thus, for example, the distributions of species restricted to southwestern Ontario, the lower mainland of British Columbia, or the Mingan Islands of Quebec, are grossly misrepresented by dots north of Lake Superior, north of Prince George, and north of Lake Mistassini, respectively.

This is a very worthwhile and useful publication that will fulfil an important function in conservation programs across Canada. The authors should be commended for persevering and carrying the rare plants program through to its logical conclusion. Hopefully, the Canadian Museum of Nature, as well as the provincial museums and all government and non-government agencies charged with the tasks of documenting and managing our flora and fauna, will continue to support efforts leading to the protection of our natural heritage.

WILLIAM J. CRINS

Ontario Ministry of Natural Resources, P.O. Box 9000, Huntsville, Ontario P0A 1K0

Liverworts and Hornworts of Southern Michigan

By Howard Crum. 1991. The University of Michigan Herbarium, Ann Arbor, Michigan. 233 pp., illus. U.S. $18 in U.S.A., U.S. $20 elsewhere.

Howard Crum, a master at producing useful bryophyte manuals for students and professionals, has written yet another easy to use identification book. This book is for students, somewhat along the line of his *Mosses of the Great Lakes Forest*, but this time the focus is on the liverworts and hornworts of southern Michigan. The book is actually an updated and more comprehensive version of William C. Steere's *Liverworts of Southern Michigan*. Michigan is now one of the few states that has recent manuals to help identify many of its liverworts, hornworts, and mosses, thanks to Howard Crum.

The manual treats the liverworts and hornworts in 42 Michigan counties in the southernmost portion of the lower peninsula. The counties are wholly or partly south of the so called "Tension Zone" in Michigan, i.e., the part of the state dividing south and north in regard to climate, soil and vegetation. The book treats 76 species in 44 genera that are presently known to occur within the region. A short introduction discusses the climate, topography, soil, and vegetation of southern Michigan, as well as habitat preferences of liverworts in the region.

The taxa are arranged in families in a systematic arrangement within the two classes, Hepaticopsida (Liverworts) and Anthocerotopsida (Hornworts). The descriptions, which are of a homespun style that are easy to read and understand, contain only the salient morphological features of each taxon. The habitat and the distribution in southern Michigan is given for each species. A nice feature of the book is the etymology of each genus and species name, something that is not always easy to find from other sources. Short discussions on how to distinguish the species from closely related ones or interesting facts, such as the fragrance of the plant, accompany the treatment of many of the taxa. An eight-page glossary and a short bibliography are in the back of the book along with 104 figures of photos and illustrations that are important in helping to understand the morphology and aid in the identification of the

plants. Howard Crum believes, as do many modern day bryologists, that illustrations are a good substitute for long and often boring technical descriptions.

I highly recommend this nicely produced book which I think the novice will find indispensable in becoming aquainted with the liverworts and hornworts of southern Michigan. Besides its use in Michigan those in southeastern Canada will find it equally useful in introducing them to these small but interesting plants.

ROBERT R. IRELAND

Canadian Museum of Nature, Botany Division, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

ENVIRONMENT

After the Ice Age: The Return of Life to Glaciated North America

By E.C. Pielou. 1991. University of Chicago Press, Chicago. ix + 355 pp., illus. U.S. $24.95.

This is a book that has been needed for a long time. Pielou uses evidence from diverse fields, mainly palaeoecology, modern biogeography, and Quaternary geoscience, to reconstruct the history of the North American landscape after the last major glaciation. The result is a scholarly yet enjoyable introduction to the North American Late Quaternary that can be perused with pleasure by both experts and general readers.

The book consists of five main sections, each comprising several chapters. The first section sets the scene by describing the changing climate of the last 20 000 years, and how ice sheets accumulate and move. Interestingly, although the book deals with climatic change, Pielou does not define climate, although she explains many other terms. Pielou describes the evidence for environmental change, concentrating on microfossils such as diatoms and pollen. She outlines techniques used to obtain climatic and environmental information from this evidence, and shows how scientists present and interpret the data, for example, in pollen diagrams. She also demonstrates how modern geographic ranges of plants and animals can provide hints about their past distributions and migration history. Pielou continues by describing how plants migrate and recolonize recently deglaciated land and considers some factors affecting their response to environmental change.

The remaining four sections form the heart of the book and tell the story of the Late Quaternary, beginning with the Late Wisconsinan glacial maximum, continuing with deglaciation, and concluding with the Holocene. Within this framework, Pielou examines the impact of environmental change on vegetation and landscape, showing how the North American terrain and its inhabitants have been constantly adjusting in response to fluctuations in climate. To illustrate her story, Pielou uses evidence from past and present distributions of plants, mammals, birds, fish, marine mammals, and insects. Among the many topics Pielou explores are the influence of proglacial lakes on the development of aquatic ecosystems, coastal refugia and the impact of rising sea-levels on plant and animal distributions, and the formation of lakes in stagnant ice terrain. She emphasizes that environmental change is continuing by concluding with an examination of Neoglaciation and the Little Ice Age.

Numerous pen-and-ink sketches illustrate the book. These include many maps and delightful portraits of some flora and fauna mentioned in the text. Pielou usually shows the sizes of animals and plants. However, maps lack scales and often lack orientation aids, for example, easily recognizable reference points such as major cities or provincial or state boundaries. Sometimes, localities mentioned in the text do not appear on associated maps. Readers unfamiliar with the geography of Canada and adjacent United States may find difficulty in following some passages without an atlas. The text contains few typographical errors. The copy I read was a publisher's page proof, and some drawings have not reproduced well; I assume that this will be corrected in the final version.

Within the study of the Late Quaternary, there are several topics that have been the subject of widespread argument and controversy and have raised intense passion among the palaeoenvironmental community. Among these, the most notorious are the debate over the vegetation and landscape of Beringia, the causes for extinction of the Pleistocene megafauna, and the question of human presence in North America before the end of the Late Wisconsinan. Part of my motivation for reading this book was to see how Pielou would handle these topics. She does not flinch from examining controversial issues. Although she sometimes leans to one side of the debate, Pielou wisely does not plump for one viewpoint. She presents the arguments clearly and provides a good introduction to some difficult debates. Her examination of contentious issues is generally very fair although not always complete. For example, she begins reviewing the "Ice-free Corridor" controversy and then segues into a description of bison evolution leaving the previous topic hanging. Naturally, in a book for general readers, Pielou cannot examine each topic in the detail it

deserves or that an expert in any of these fields might wish to see.

Most references Pielou cites are from the 1970s and 1980s. She wrote the epilogue at New Year 1989, so some recent developments are not covered. Her discussion of biogeography and palaeoecology is excellent, varied, and interesting, but I feel that her handling of archaeological material is noticeably weaker. She seems less confident and comfortable dealing with this topic. Her evaluation is less balanced, particularly for the technological and cultural aspects of human history. For example, Pielou presents the argument that people may have migrated south from Beringia along more extensive coastal areas in the Late Wisconsinan, but she does not mention whether there is any evidence that people at this time had the requisite maritime technology to do this. I think this is a minor flaw because human history is not a major focus of the story.

The publication of this captivating book is timely and topical. Pielou's strength is her ability to synthesize large amounts of disparate information and make it both comprehensible and highly readable. Recent media interest in climatic warming and global change has highlighted the need for a straightforward explanation of past environmental variations. As Quaternary scientists, we have a duty to educate the public about the necessity and value of research into what, for most people, is a dim, distant, and intangible past. By making environmental history fascinating and vital, Pielou's fine book is a splendid ambassador for the Late Quaternary.

ALWYNNE B. BEAUDOIN

Archaeological Survey, Provincial Museum of Alberta, 12845-102nd Avenue, Edmonton, Alberta T5N 0M6

Canada's Missing Dimension: Science and History in the Canadian Arctic Islands

By C. R. Harington, Editor. 1990. National Museum of Natural Sciences, Ottawa. 2 Volume set, 855 pp., illus. $25.

According to the preface, these two volumes contain many of the papers presented at an international meeting ("The Canadian Arctic Islands: Canada's Missing Dimension") held in Ottawa in November 1987, plus "some pertinent new contributions". Some of the papers are technical accounts of individual research projects, and some are general surveys of broad topics; there are enough of the latter to make the work valuable to any naturalist with arctic interests especially since the price is so astonishingly low.

The volumes are printed in unusually big type on good quality paper and are strongly bound in soft covers. The illustrations are large and clear. And there is a detailed index, a rare boon in a multi-authored work, for which the editor deserves special thanks.

Some examples of interesting review papers give an idea of the coverage: Roy M. Koerner on climatic changes over the last 100 000 years, inferred using ice cores collected from an ice cap in Ellesmere Island; S. A. Edlund on the bioclimatic zones of the Arctic Islands; H. V. Danks on the adaptations of insects to arctic conditions; Henri Ouellet on the geographic ranges of Arctic Island birds and the regions from which they immigrated as the last ice sheets melted; David R. Gray on the life of warm-blooded animals in the arctic winter; Robert McGhee on Inuit settlement in the High Arctic before the rigors of the Little Ice Age led to their departure; Charles D. Arnold and Karen McCullough on the development of Thule culture, first on Banks Island (Nelson River) and later off Ellesmere Island (Skraeling Island); William Barr on the part played by a young French Naval officer (Emile de Bray) in the search for Franklin; and Mary R. Dawson on life on the Arctic Islands in the Tertiary, as inferred from vertebrate fossils. Unfortunately she does no more than mention the most tantalizing problem they raise; as she says, because "the Arctic Eocene combination of warm temperatures and polar light conditions does not exist today, it is difficult to interpret animal and plant responses to these extinct environmental conditions". How could she have refrained from some informed speculation on this fascinating puzzle?

Oddly, the volumes contain no contributions on arctic geomorphology. This is a pity; assuming that global warming has already begun, and that the Arctic is destined to be the region most strongly affected, a summary of modern research on thermokarst phenomena would have been welcome.

The comment with which one author (Claude L. Labine) concludes his paper should be pondered. He writes: "... one of the main drawbacks to Arctic research as a whole is the lack of an explicit, committed northern policy by the federal government". This is disturbing, and naturalists, who are becoming a growing force politically, should take note of it.

E. C. PIELOU

R.R.1, Denman Island, British Columbia V0R 1T0

Man in the Landscape; a Historic View of the Esthetics of Nature

By Paul Shepard. 1991. Texas A&M University Press, College Station. 336pp., illus. U.S. $24.50.

It is important to note that this 1991 book is in fact an unrevised reprint of a 1967 book, which was in turn based on a Ph.D thesis of 1954. So much has happened over the intervening years that the historical context must be kept in mind. Shepard explains in the new preface that he resisted making changes on the grounds that the book is part of a period when "'interdisciplinary' study was considered in bad taste", and must be read in that context. A revision would be, in fact, a completely new document. The logic is, on the whole, convincing. The book is about societal perceptions of nature, and the chance to reflect on how these very perceptions have changed since the book was first written can be stimulating for the attentive reader.

The rather anachronistic title is a case in point. Shepard regrets it in the first paragraph of the new preface, but in fact an extended early section in the book is what would today be called ecofeminism. In this case, and at many other points in the book, it is presentation, not content, that has aged. Only in a few sections is the judgement less obvious. A rather feeble defence of sport hunting, for example, is memorable only because it sets up, in a later chapter, the aphorism that conservationists "have no blood on their fingers, but no blood in them either".

The book is an extended articulated argument of great breadth. Shepard does not attempt to defend each point in an academic way. Instead, he coaxes the reader to suspend critical faculties, and to trust him with the rather large leaps of logic that are required to cover the huge intellectual territory he has taken on. The argument takes in everything from the physiology of the vertebrate eye, the place of gardens in society, sense of place, and the history of mass tourism. It is almost impossible to summarize such an argument as a conclusion in a few words, and probably counterproductive as well (getting there is more than half the fun), but a quotation from late in the book can give the flavour of how the threads are brought together:

> This was the visual surprise of the Western wilderness: truly wild places that resembled civilization's most ornamental achievement – the estate park – which was, in turn, linked with an image of paradise. William Gilpin's *The Parks of Colorado,* published in 1866, was a description of genuine wilderness, although a park had never been wilderness in Europe.

It is a tribute to the organization of the argument that such conclusions appear both fascinating and inevitable when they eventually appear, after long sections of preparation.

This is not a book that can be browsed. However, for critical readers with some time to spend, it repays careful attention.

JOHN MIDDLETON

Institute of Urban and Environmental Studies, Brock University, St. Catharines, Ontario L2S 3A1

Restoration Ecology: A Synthetic Approach to Ecological Research

Edited by W. R. Jordan III, M. E. Gilpin, and J. D. Aber. 1990. Cambridge University Press, Cambridge. viii + 342 pp., illus. U.S. $24.95.

Restoration Ecology is the outcome of a symposium held in Madison on 11 and 12 October, 1984. The symposium attracted an eclectic group of individuals from a variety of ecological interests. The book reflects the variety of individuals that attended.

The book attempts to unite the two fields of theoretical and applied ecology. With examples from many ecosystems, a variety of theoretical questions are brought forth in an attempt to provide a method of testing through the utilization of ecosystem restoration opportunity examples. The book suggests questions normally answered with research using complex communities may be answered by restoring and/or attempting to restore complete ecosystems.

The book is aimed at an audience of individuals with a solid base of knowledge of ecology. This is not a book to be read on a whim, but for those versed in the field the book should be easy reading. *Restoration ecology* presents its aims and goals with clarity. The chapters complement each other and follow the intended theme.

Anyone interested in ecosystem restoration work would be advised to obtain a copy. Those people interested in theoretical ecology should also find *Restoration ecology* of interest.

M. P. SCHELLENBERG

434 4th Ave SE, Swift Current, Saskatchewan S9H 3M1

Ethics of Environment and Development: Global Challenge and International Response

Edited by J. R. Engel and J. G. Engel. 1990. University of Arizona Press, Tuscon. 264 pp. U.S. $29.95.

The book is difficult to start. However, I enjoyed most of the chapters, with some rather notable exceptions, and I was impressed by the erudition and scholarship of several of the authors. I recommend this book to people interested in conservation at the global level, and particularly for those who have read the International Union for the Conservation of Nature and Natural Resources (IUCN) publication: *World Conservation Strategy* (1980, 1991).

This volume was produced after the 1986 Conference on Conservation and Development in Ottawa, by the IUCN Ethics Working Group. Its purpose is to clarify ethical principles in sustainable development, and to examine the relationships between environmental ethics and religious beliefs among the world's five major religions. The main message is that human value systems must change in the face of the failure by society to protect the environment. The entire model of modern industrial development is portrayed as awry, with its hierarchies of power and wealth, its view of the world as a machine, and its underpinning of unlimited material growth. Current views are that conservation competes with industry for resources. Governments have embraced "sustainable development", but the rhetorical question "what has changed?", clearly strikes a discordant note (witness the Rafferty-Alemeda Dam, James Bay 2, and the Oldman River Dam). Instead, the book urges a new post-modern development paradigm based on an interpretation of sustainable development that is neither self-serving nor ethically bankrupt. Humans must recognize that we are members of a community, and not masters of it. Each author argues for a holistic approach to development, that recognizes the inextricable linkage between poverty, population growth, and environmental degradation. Development models must be drawn from ecology and not from chemistry, physics, and computer science. In the best chapter of the book, by Holmes Rolston, the argument is made that science-based societies need to reform their ethics because science-based values are not part of the solution, but rather they are part of the problem.

The intention of the book is not polemical, however, it surely meets the criteria. The authors strive to rationalize failure among the masses to heed their religious teachings in every day life to protect and respect their environment. Environmental destruction is rooted in individual survival or greed, which is placed above religious doctrine. The single major failing in the book is that the issue of overpopulation, foremost among the root causes of environmental degradation, is either deftly skated around or not dealt with at all. A second difficulty I found with the book was that the considerable repetition of the same message detracted, ultimately, from that message. A chapter to avoid was written by Hilkka Pietilä, entitled "The daughters of the earth: Women's culture as a basis for sustainable development". In it we are assured that men are solely responsible for all environmental woes, and that women are "one with the earth" and would never permit environmental tragedy. The depth of ignorance, intellectual dishonesty, and scientific vacuity displayed in this chapter detracts so much from the book, that one wonders why the editors chose to include it.

The message from this work should be well-heeded: humans have replaced ecology, the logic of the home, with economics, the logic of resource use. If humanity is the only species capable of saving the planet from its hell-bent journey to destruction, then we need to change our values, alter our courses of action, and do it soon.

IAN D. THOMPSON

Forestry Canada, Petawawa National Forestry Institute, Box 200, Chalk River, Ontario K0J 1J0

Discordant Harmonies: A New Ecology for the Twenty-First Century

By Daniel B. Botkin. 1990. Oxford University Press, New York. xii + 241 pp., illus. U.S. $19.95.

Daniel Botkin proposes with this work that to achieve harmony with nature "we must understand the character of nature undisturbed, the discordant harmony ...". To realize this new view the human race "must break free of old assumptions and old myths about nature and ourselves ...". To support these statements the author discusses man's differing concepts of nature through time. Examples are provided from his own experiences and documented cases demonstrating problems with each concept of nature. This harmony with nature is suggested to be necessary in order to deal with global environmental problems we, the human race, face today.

The book is written with both the academic and the layperson in mind. The chapters follow a logical and fluent order. The reader is introduced to the various concepts through examples. On the whole, the book is well documented, but does not attempt to be nor is it intended to be an exhaustive review of the literature. *Discordant Harmonies* is meant to be an argument for Daniel Botkin's means of approaching today's global environmental problems and succeeds.

The book is well written and its contents deserve to be read by those with a sincere interest in ecology and today's global environmental problems.

M. P. SCHELLENBERG

434 4th Ave SE, Swift Current, Saskatchewan S9H 3M1

MISCELLANEOUS

Elton's Ecologists: A History of the Bureau of Animal Population

By Peter Crowcroft. 1991. University of Chicago Press, Chicago. 177 pp., Cloth U.S. $35; paper U.S. $14.95.

Elton's Ecologists is an informal history of the now defunct Bureau of Animal Population (BAP) at Oxford University by alumnus Peter Crowcroft. During its brief thirty-five-year existence (1932-1967), the Bureau attracted promising students from Britain, the Commonwealth, and the United States who had come to Oxford — sometimes without notice — to work with the institute's first and only director, the famed ecologist Charles Elton. Under Elton's fatherly guidance, these students, along with the Bureau's small staff and occasional visiting scholar, performed pioneering research in animal population dynamics. Indeed, it could be argued that the BAP was one of the most influential scientific institutions of its day.

Written out of a sense of obligation to the Bureau and Elton, Crowcroft's history of the BAP is a highly readable one. He describes the Bureau's beginnings and growth, its various homes and facilities, its ongoing struggle for adequate financial support, and the circumstances surrounding its demise upon Elton's retirement. He also provides an intimate, at times humorous, discussion of the staff and students and their various research endeavours. Through it all, Elton or "the boss" is a central figure, and the book is as much about him as it is about the institute.

Those readers who are interested in learning about how the BAP's research activities fit into the overall development of animal ecology will have to look elsewhere. Those who are seeking a more formal biography of Elton will also be disappointed. Crowcroft's purpose is much more simpler but nonetheless invaluable; he provides the view from the inside by someone who was there — something which is often written too late or never at all.

W. A. WAISER

Department of History, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

Carl Akeley: Africa's Collector, Africa's Savior

By Penelope Bodry-Sanders. 1991. Paragon House, New York. xviii + 298 pp., illus. U.S. $19.95.

Carl Akeley bestrode his time and space as a bold hunter, explorer, inventor, and museum artist in all respects: taxidermist, sculptor, and designer of galleries. The author presents his career sympathetically and clearly: the twelve year-old stuffing a friend's beloved canary; the early years at Ward's Natural Science Establishment, including the work on Jumbo, lamented victim of a locomotive, and friendship with William Morton Wheeler; first diorama and wife in Milwaukee; work at the Field Museum; celebrated hand killing of a leopard during the first trip to Africa; expeditions for the American Museum of Natural History in the face of dangers and hardships (akin to Joseph Conrad's *Heart of Darkness* as the author appropriately points out) and yielding great collections, association with Henry Fairfield Osborn and Teddy Roosevelt, and fame like that of his colleague Roy Chapman Andrews; the nature films and superb sculptures; his second marriage and change in attitude toward nature during the gorilla hunt; his African death and legacy of lasting value at the American Museum. Descriptions of the author's pilgrimage to his grave are given at the beginning and end of the book and thus frame the text with the esteem in which she holds her subject. Such admiration might be expected in a former archivist of that Museum, and certainly contrasts with the sharply ideological dissection of Akeley and others in the recent *Primate Visions* by Donna Haraway.

Along with a few infelicities, there are many strengths in this biography. The illustrations, the relevance of other literature, and background material on political, sociological, and taxidermic topics are all useful. Various aspects of Akeley's character are considered, including his prowess as an inventor of such devices as the cement gun, swivel camera, and others for the military during World War I. His transformation from hunter to conservationist parallels that of Aldo Leopold (whose biography by Curt Meine was reviewed in *The Canadian Field-Naturalist* 103: 467-468). Beyond the recounting of Akeley's life and times, the book provides a perspective on such contemporary issues as conservation, the social functions of museums, and the development of Africa. What emerges is a full and balanced volume well worth reading.

PATRICK W. COLGAN

Canadian Museum of Nature, P.O. Box 3443, Station D, Ottawa, Ontario K1P 6P4

NEW TITLES

Zoology

Animal amazing. 1991. By Judith Herbst. Antheneum, New York. 180 pp. U.S.$13.95.

The ant and the peacock: altruism and sexual selection from Darwin to today. 1991. By Helena Cronin. Cambridge University Press, New York. c400 pp., illus. cU.S.$34.50.

†**Back from the brink: the road to muskox conservation in the Northwest Territories.** 1991. Arctic Institute of North America, University of Calgary, Calgary. xvi + 127 pp., illus. $20 + $3 postage.

*__The bats of Texas.__ 1991. By David J. Schmidly. Texas A & M University Press, College Station. xv + 188 pp., illus. Cloth U.S.$34.50; paper U.S.$19.95.

*__Birds and islands: travels in wild places.__ 1991. By Ronald Lockley. Witherby (Canadian distributor McClelland and Stewart, Markham, Ontario). 237 pp., illus. $39.95.

†**Bryozoan evolution.** 1991. By Frank K. McKinney and Jeremy B. C. Jackson. University of Chicago Press, Chicago. xii + 238 pp., illus. U.S.$15.95.

The Cambridge encyclopedia of ornithology. 1991. *Edited by* Michael Brooke and Tim Birkhead. Cambridge University Press, New York. c320 pp., illus. U.S.$49.50.

†**Care of the wild: first aid for all wild creatures.** 1991. By William J. Jordon and John Hughes. University of Wisconsin Press, Madison. 236 pp., illus. Cloth U.S.$27.50; paper U.S.$11.95.

*__The development and evolution of butterfly wing patterns.__ By H. Frederick Nijhout. Smithsonian Institute Press, Washington. xvi + 297 pp., illus. U.S.$20 + postage.

Discovering sharks: a volume honoring the work of Stewart Springer. 1991. Edited by Samuel H. Gruber. American Littoral Society, Highlands, New Jersey. 122 pp., illus. U.S.$10.

*__A guide to the birds of Nepal.__ 1991. By Carol and Tim Inskipp. 2nd edition. Smithsonian Institute Press, Washington. 400 pp., illus.

*__Language and intelligence in monkeys and apes.__ 1990. By Sue Parker and Kathleen Gordon. Cambridge

University Press, Cambridge, Massachusetts. xviii + 590 pp., illus. U.S.$65.

*__The magpies: the ecology and behavior of black-billed and yellow-billed magpies.__ 1991. By Tim Birkhead. Poyser (Distributed by Academic (Harcourt Brace Jovanovich, San Diego)). 272 pp., illus. U.S.$39.95.

__Mammoths, mastodonts, and elephants: biology, behavior, and the fossil record.__ 1991. By Gary Haynes. Cambridge University Press, New York. c432 pp., illus. cU.S.$69.50.

*__Prairiewater: watchable wildlife at Beaverhills Lake, Alberta.__ 1991. By R. Dekker. BST Publications, Edmonton. 144 pp., illus. $19.95.

†__Proceedings of the International Herring Symposium.__ 1991. *Edited by* V. Wespestad, J. Collie, and E. Collie. Symposium in Anchorage October 23–25, 1990. Alaska SeaGrant College Program, Fairbanks. x + 672 pp., illus. U.S.$14.

†__The secret world of animals.__ 1991. By the National Museum of Canada. University Book Sales and Services, 4823 Sherbrook Street West, Westmount, Quebec H3Z 1G7. Audio casettes: 4 in English, 1 in French. $10.95 each.

__Tracking dinosaurs: a new look at an ancient world.__ 1991. By Martin Lockley. Cambridge University Press, New York. c249 pp., illus. Cloth U.S.$39.50; paper U.S.$14.95.

*__Waterbirds of the Strait of Georgia.__ 1991. By Eileen C. Campbell, R. Wayne Campbell, and Ronald T. McLaughlin. British Columbia Waterfowl Society, Delta, British Columbia. 60 pp., illus.

Botany

__Biology of vines.__ 1991. *Edited by* F. E. Putz and H. A. Mooney. Cambridge University Press, New York. c448 pp., illus. cU.S.$75.

__British plant communities, volume 2: mires and heaths.__ 1991. *Edited by* J. S. Rodwell. Cambridge University Press, New York. c700 pp., illus. cU.S.$195.

__Bryophyte systematics.__ 1991. *Edited by* N. G. Miller. Advances in Bryology Volume 4. Cramer, Stuttgart. c220 pp. cDM 220.

*__Forest management in Australia.__ 1991. Edited by F. H. McKinnell, E. R. Hopkins, and J. E. D. Fox. Surrey Beatty, Chipping Norton, Australia. 380 pp., illus. A $72 + postage.

__Indian hornworts: a taxonomic study.__ 1991. By A. K. Asthana and S. C. Srivastava. Cramer, Stuttgart. xii + 230 pp., illus. cDM 120.

*__Manual of vascular plants of northeastern United States and adjacent Canada.__ 1991. By Henry A. Gleason and Arthur Cronquist. Second edition. New York Botanical Garden, Bronx. lxxv + 910 pp. U.S.$74.60 in U.S.A.; U.S.$76.90 elsewhere.

__The vascular plants of British Columbia, Part 2 — dicotyledons (Diapensiaceae through Portulacaceae).__ 1990. *Edited by* George W. Douglas, Gerald B. Straley, and Del Meidinger. British Columbia Ministry of Forests, Victoria.

__Vegetation of New Zealand.__ 1991. By Peter Wardle. Cambridge University Press, New York. c608 pp., illus. cU.S.$135.

Environment

__Beyond natural selection.__ 1991. By Robert G. Wesson. MIT Press, Cambridge, Massachusetts. xv + 309 pp., illus. U.S.$29.95.

*__Foundations of ecology: classic papers with commentaries.__ 1991. *Edited by* Leslie A. Real and James H. Brown. University of Chicago Press, Chicago. 1000 pp. Cloth U.S.$70; paper U.S.$27.50.

*__The greater Yellowstone ecosystem: redefining America's wilderness heritage.__ 1991. *Edited by* Robert B. Keiter and Mark S. Boyce. Yale University Press, New Haven. xvii + 428 pp., illus. U.S.$45.

*__In a patch of fireweed: a biologist's life in the field.__ 1991. By Bernd Heinrich. Paperback reissue of 1984 edition. Harvard University Press, Cambridge, Massachusetts. viii + 194 pp., illus. Cloth U.S.$20; paper U.S.$8.95.

__Leaving Eden: to protect and manage the earth.__ 1991. By E. G. Nisbet. Cambridge University Press, New York. c465 pp., illus. Cloth U.S.$42.50; paper U.S.$14.95.

†__Nature conservation 2: the role of corridors.__ 1991. *Edited by* Denis A. Saunders and Richard J. Hobbs. Surrey Beatty, Chipping Norton, NSW, Australia. xii + 442 pp., illus. A $80 + postage.

__Population regulation and dynamics.__ 1991. *Edited by* M. P. Hassell and R. M. May. Cambridge University Press, New York. c/80 pp. cU.S.$69.50.

__A systems analysis of the global boreal forest.__ 1991. *Edited by* Herman H. Shugart, Rik Leemans, and Gordon B. Bonan. Cambridge University Press, New York. c545 pp., illus. cU.S.$75.

Miscellaneous

*__Aldo Leopold, his life and work.__ 1991. By Curt Meine. University of Wisconsin Press, Madison. xv + 638 pp., illus. U.S.$19.95.

__CRC handbook of ethological, ecological, and evolutionary terminology.__ 1991. By Edward M. Barrows. CRC Press, Boca Raton, Florida. c816 pp. cU.S.$195 in U.S.A.; cU.S.$234 elsewhere.

__The evolution of reproductive strategies.__ 1991. Edited by T. R. E. Southwood, P.H. Harvey, and L. Partridge.

Cambridge University Press, New York. c150 pp. cU.S.$64.50.

The innocent assassins: biological essays on life in the present and distant past. 1991. By Bjorn Kurten. Columbia University Press, New York. 196 pp., illus. U.S.$19.95.

*__Pioneer ecologist: the life and work of Victor Ernest Shelford__, 1877-1968. 1991. By Robert A. Crocker. Smithsonian Institute Press, Washington. xviii + 222 pp. + plates. U.S.$27.50 + postage.

Books for Young Naturalists

Amazing beetles. 1991. By John Still. Knopf, New York. 29 pp., illus. U.S.$6.95.

Animals and the new zoos. 1991. By Patricia Curtis. Lodestar, New York. vi + 59 pp., illus. U.S.$15.95.

Animal defenses. 1991. By Jeremy Cherfas. Lerner, Minneapolis. 31 pp., illus. U.S.$11.95.

Animals in jeopardy. 1991. By Diane Costa de Beauregard. Translated by Vicki Bogard. Young Discovery, Ossington, New York. 35 pp., illus. U.S.$4.95.

At home in the rain forest. 1991. By Diane Willow. Charlesbridge, Watertown, Massachusetts. 30 pp., illus. U.S.$14.95.

Batman: exploring the world of bats. 1991. By Laurence Pringle. Scribner's, New York. 48 pp., illus. U.S.$13.95.

Book of endangered species: rare, vulnerable, and endangered species of the world. 1991. By the National Wildlife Federation. Earthbooks, Denver. 65 pp., illus. U.S.$5.95.

Botany: 49 more science fair projects. 1991. By Robert L. Bonnet and G. Daniel Keen. TAB, Blue Ridge Summit, Pennsylvania. 144 pp.

Busy, busy, squirrels. 1991. By Colleen Stanley Bare. Cobblehill, New York. 32 pp., illus. U.S.$12.95.

Cats, big and little. 1991. By Beatrice Fontanel. Translated by Vicki Bogard. Young Discovery, Ossington, New York. 35 pp., illus. U.S.$4.95.

Danger on the arctic ice. 1991. By Elisabeth Sackett. Sierra Club, San Francisco. 24 pp., illus. U.S.$12.95.

Dawn to dusk in the Galapagos: flightless birds, swimming lizards, and other fascinating creatures. 1991. By Rita Golden Gelman. Little, Brown, Boston. 43 pp., illus. U.S.$16.95.

A desert year. 1991. By Carol Lerner. Morrow Junior, New York. 48 pp., illus. U.S.$13.95.

Eight legs. 1991. By D.M. Souza. Carolrhoda, Minneapolis. 40 pp., illus. U.S.$12.95.

†**A field guide to endangered wildlife coloring book.** 1991. By Richard K. Walton. Houghton Mifflin, Boston. 64 pp., illus. + plates. U.S.$4.95.

†**A field guide to tropical forests coloring book.** 1991. By John Kricher and Gordon Morrison. Houghton Mifflin, Boston. 64 pp., illus. + plates. U.S.$4.95.

Flowers, trees, and other plants. 1991. By Angela Royston. Watts, New York. 40 pp., illus. U.S.$11.40.

Frog. 1991. By Michael Chinery. Troll, Mahwah, New Jersey. 32 pp., illus. Cloth U.S.$9.89; paper U.S.$2.95.

Insects around the house. 1991. By D. M. Souza. Carolrhoda, Minneapolis. 40 pp., illus. U.S.$12.95.

The living pond. 1991. Nathalie Tordjam. Translated by Vicki Bogard. Young Discovery, Ossington, New York. 35 pp., illus. U.S.$4.95.

Living treasure: saving earth's threatened biodiversity. 1991. By Laurence Pringle. Morrow, New York. 112 pp., illus. U.S.$12.95.

Insect zoo. 1991. By Susan Meyers. Lodestar, New York. 45 pp., illus. U.S.$16.95.

Meeting the whales: the Equinox guide to the giants of the deep. 1991. By Erich Hoyt. Camden House, Willowdale, Ontario. 69 pp., illus. Cloth $17.95; paper $9.95.

Mountain lion: puma, panther, painter, cougar. 1991. By Sandra Robinson-Chisholm. Roberts Rinehart, Niwot, Colorado. 59 pp., illus. U.S.$6.95.

My first green book. 1991. By Angela Wilkes. Knopf, New York. 48 pp., illus. U.S.$12.

A night and day in the desert. 1991. By Jennifer Owings Dewey. Little, Brown, Boston. 30 pp., illus. U.S.$15.95.

175 more science experiments to amuse and amaze your friends: experiments! tricks! things to make! 1991. By Terry Cash. Random House, New York. 168 pp., illus. U.S.$10.95.

Pomona: the birth of a penguin. 1991. By Catherine Paladino. New England Aquarium (Watts, New York). 32 pp., illus. U.S.$12.95.

The puffins are back! 1991. By Gail Gibbons. Harper Collins, New York. 32 pp., illus. U.S.$13.95.

Recycling: the earth at risk. 1991. By Rebecca Stefoff. Chelsea House, New York. 118 pp., illus. U.S.$19.95.

Sierra. 1991. By Diane Siebert. Harper Collins, New York. 32 pp., illus. U.S.$14.95.

The Simon and Schuster young reader's book of animals. 1991. By Martin Walters. Simon and Schuster. 192 pp., illus. Cloth U.S.$12.95; paper U.S.$7.95.

Under the sea from A to Z. 1991. By Anne Doubilet. Crown, New York. 26 pp., illus. U.S.$15.99.

Where does the trail lead? 1991. By Burton Albert. Simon and Schuster, New York. 32 pp., illus. U.S.$13.95.

Wings for my flight: the peregrine falcons of Chimney Rock. 1991. By Marcy Cottrell-Houle. Addison-Wesley, New York. 208 pp., illus. U.S.$17.95.

*assigned for review
†available for review

Advice to Contributors

Content

The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

Manuscripts

Please submit, **to the Editor,** in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

Type the manuscript on standard-size paper, if possible use paper with numbered lines, **double-space throughout**, leave generous margins to allow for copy marking, and **number each page**. For Articles and Notes provide a bibliographic strip, an abstract and a list of key words. Generally words should not be abbreviated but use SI symbols for units of measure. Underline only words meant to appear in italics. The names of authors of scientific names should be omitted except in taxonomic manuscripts or other papers involving nomenclatural problems. "Standard" common names (with initial letters capitalized) should be used at least once for all species of higher animals and plants; all should also be identified by scientific name.

The names of journals in the Literature Cited should be written out in full. Unpublished reports should not be cited here but placed in the text or in a separate documents section. Next list the captions for figures (numbered in arabic numerals and typed together on a separate page) and present the tables (each titled, numbered consecutively in arabic numerals, and placed on a separate page). Mark in the margin of the text the places for the figures and tables.

Extensive tabular or other supplementary material not essential to the text, typed neatly and headed by the title of the paper and the author's name and address, should be submitted in duplicate on letter-size paper for the Editor to place in the Depository of Unpublished Data, CISTI, National Research Council of Canada, Ottawa, Canada K1A 0S2. A notation in the published text should state that the material is available, at a nominal charge, from the Depository.

The **Council of Biology Editors Style Manual**, Fourth edition (1978) available from the American Institute of Biological Sciences, and **The Canadian Style: A Guide to Writing and Editing**, Department of the Secretary of State and Dundurn Press Ltd (1985) are recommended as general guides to contributors but check recent issues (particularly in literature cited) for exceptions in journal format. Either "British" or "American" spellings are acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary, Webster's New International Dictionary** and le **Grand Larousse Encyclopédique** are the authorities for spelling.

Illustrations

Photographs should have a glossy finish and show sharp contrasts. Photographic reproduction of line drawings, **no larger than a standard page**, are preferable to large originals. Prepare line drawings with India ink on good quality paper and letter (don't type) descriptive matter. Write author's name, title of paper, and figure number on the lower left corner or on the back of each illustration.

Reviewing Policy

Manuscripts submitted to *The Canadian Field-Naturalist* are normally sent for evaluation to an Associate Editor (who reviews it or asks another qualified person to do so), and at least one other reviewer, who is a specialist in the field, chosen by the Editor. Authors are encouraged to suggest names of suitable referees. Reviewers are asked to give a general appraisal of the manuscript followed by specific comments and constructive recommendations. Almost all manuscripts accepted for publication have undergone revision — sometimes extensive revision and reappraisal. **The Editor makes the final decision** on whether a manuscript is acceptable for publication, and in so doing aims to maintain the scientific quality, content, overall high standards and consistency of style, of the journal.

Special Charges — Please take special note

Authors **must share in the cost of publication** by paying $70 for each page in excess of five journal pages, plus $7 for each illustration (any size up to a full page), and up to $70 per page for tables (depending on size). Reproduction of color photos is extremely expensive; price quotations may be obtained from the Business Manager. Reprint order forms are included when galley proofs are sent to authors. If grant or institutional funds are available, we ask authors to defray a higher proportion of the cost of publishing, $70 per page for all published pages. Government institutions are expected to pay the full cost of publication. Authors must also be charged for their changes in proofs.

Limited journal funds are available to help offset publication charges to authors with minimal financial resources. Requests for financial assistance should be made to the Business Manager when the manuscript is accepted.

Reprints

An order form for the purchase of reprints will accompany the galley proofs sent to the authors.

FRANCIS R. COOK, Editor
RR 3 North Augusta, Ontario K0G 1R0

TABLE ON CONTENTS *(concluded)*

First report of the Threespine Stickleback, *Gasterosteus aculeatus*, from Sable Isand
DAVID J. MARCOGLIESE 264

First record of the Minke Whale, *Balaenoptera acutorostrata*, in Manitoba Waters
DONALD L. PATTIE and MARC WEBBER 266

Stellar Sea Lion, *Eumetopias jubatus*, predation on Glaucous-winged Gulls, *Larus glaucescens*
DONNA O'DANIEL and JAMES SCHNEEWEIS 268

News and Comment

Amendment to the Constitution of *The Ottawa Field-Naturalists' Club* and Request for Additional Proposals — Editor's Report for Volume 105 (1991) — Errata for *The Canadian Field-Naturalist* 105 (4) 269

The Arctic Collection of the Fowler Herbarium, Queen's University, 1828-1977
A. CROWDER, J. TOPPING, A. E. GARWOOD, M. HANDFORD, C. VARDY, and H. BRETZKE 272

Book Reviews

Zoology: Ecology and Classification of North American Freshwater Invertebrates — The Evolution of Parental Care — Phylogeny, Ecology, and Behavior — Grizzly Cub: Five Years in the Life of a Bear — The Jackson Hole Elk Herd: Intensive Wildlife Management in North America — The Natural History of the Wild Cats — Frozen Fauna of the Mammoth Steppe: The Story of Blue Babe — Wild Echos: Encounters with the Most Endangered Animals in North America — Golden-crowned Kinglets: Treetop Nesters of the North Woods — "Language" and Intelligence in Monkeys and Apes: Comparative Developmental Perspectives — Pacific Salmon Life Histories — Immature Insects, Volume 2 — A Guide to the Birds of Nepal — Harp Seal, Man, and Ice — Moosebirds and Sandpeeps: Birds in and Around Fundy National Park — The Traveling Birder: 20 Five-star Birding Vacations — Waterbirds of the Strait of Georgia — The Birds of Japan 278

Botany: Rare Vascular Plants in Canada: Our Natural Heritage — Liverworts and Hornworts of Southern Michigan 291

Environment: After the Ice Age: The Return of Life to Glaciated North America — Canada's Missing Dimension: Science and History in the Canadian Arctic Islands — Man in the Landscape: A Historic View of the Esthetics of Nature — Restoration Ecology: A Synthetic Approach to Ecological Research — Ethics of Environment and Development: Global Challenge and International Response — Discordant Harmonies: A New Ecology for the Twenty-first Century 293

Miscellaneous: Elton's Ecologists: A History of the Bureau of Animal Population — Carl Akeley: Africa's Collector, Africa's Savior 297

New Titles 298

Advice to Contributors 302

Mailing date of the previous issue 106(1) : 21 December 1992

Articles

Arctic Cisco, *Coregonus autumnalis*, distribution, migration and spawning in the Mackenzie River
ROBERT EARL DILLINGER, Jr., TIMOTHY P. BURT, and JOHN M. GREEN 175

Home range and foraging habitat of American Crows, *Corvus brachyrhynchos*, in a waterfowl breeding area in Manitoba
BRIAN D. SULLIVAN and JAMES J. DINSMORE 181

Effects of aspen succession on Sharp-tailed Grouse, *Tympanuchus phasianellus*, in the Interlake Region of Manitoba ROBERT P. BERGER and RICHARD K. BAYDACK 185

Discovery of a living 900 year-old Northern White Cedar, *Thuja occidentalis*, in northwestern Quebec SYLVAIN ARCHAMBAULT and YVES BERGERON 192

Electrophoretic identification of the Marbled Salamander, *Ambystoma opacum*, on Kellys Island, Lake Erie LESLIE ANTHONY LOWCOCK and JAMES P. BOGART 196

Red Foxes, *Vulpes vulpes*, as biological control agents for introduced Arctic Foxes, *Alopex lagopus*, on Alaskan Islands EDGAR P. BAILEY 200

First record for Canada of the Rudd, *Scardinius erythrophthalmus*, and notes on the Introduced Round Goby, *Neogobius melanostomus*
E. J. CROSSMAN, E. HOLM, R. CHOLMONDELEY, and K. TUININGA 206

Comparison between urban and rural bird communities in prairie Saskatchewan: urbanization and short-term population trends NAVJOT S. SODHI 210

Northward invading none-native vascular plant species in and adjacent to Wood Buffalo National Park, Canada
ROSS W. WEIN, GEROLD WEIN, SIEGLINDE BARRET, and WILLIAM J. CODY 216

Food habits and observations of the hunting behaviour of Arctic Foxes, *Alopex lagopus*, in Svalbard PÅL PRESTRUD 225

Preliminary evidence for fractional spawning by the Northern Redbelly Dace, *Phoxinus eos* PERCE M. POWLES, S. FINUCAN, M. VAN HAAFTEN, and R. ALLEN CURRY 237

Ontogenetic changes in habitat use by juvenile turtles, *Chelydra serpentina* and *Chrysemys picta* JUSTIN D. CONGDON, STEVE W. GOTTE, and ROY M. McDIARMID 241

Notes

A method for decreasing trap mortality of *Sorex*
JOHN A. YUNGER, RICHARD BREWER, and RHONDA SNOOK 249

Bat hibernacula on Lake Superior's north shore, Minnesota BRUCE KNOWLES 252

Breeding Gadwalls, *Anas strepera*, near Yellowknife, Northwest Territories
MICHAEL A. FOURNIER, DAVID L. TRAUGER, JAMES E. HINES and DAVID G. KAY 254

Additional mixed-age Brown Bear, *Ursus arctos*, associations in Alaska
FREDERICK C. DEAN, RICK MCINTYRE, and RICHARD A. SELLERS 257

Westward range extension for the Yellow Mountain Saxifrage, *Saxifraga aizoides*: a new vascular plant species to Alaska CHARLES T. SCHICK 260

Record of a Redhead, *Aythya americana*, laying eggs in a Northern Harrier, *Circus cyaneus*, nest JOSEPH P. FLESKES 263

concluded on inside back cover

ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 106, Number 3 July-September 1992

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency The Right Honourable Ramon John Hnatyshyn, P.C., C.C., C.M.M., Q.C.,
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Edward L. Bousfield
Irwin M. Brodo
William J. Cody
Ellaine Dickson
William G. Dore
R. Yorke Edwards
Anthony J. Erskine
Clarence Frankton
Claude E. Garton
W. Earl Godfrey
C. Stuart Houston
Thomas H. Manning
Don E. McAllister
Stewart D. MacDonald
Verna Ross McGiffin
Hue N. MacKenzie
Eugene G. Munroe
Robert W. Nero
Hugh M. Raup
Loris S. Russell
Douglas B.O. Savile
Pauline Snure
Mary E. Stuart
Sheila Thomson

1992 Council

President: Frank Pope
Vice-President: Michael Murphy
Recording Secretary: Connie Clark
Corresponding Secretary: Eileen Evans
Treasurer: Gillian Marston

Ronald E. Bedford
Barry Bendell
Fenja Brodo
Steve Blight
Lee Cairnie
Martha Camfield
William J. Cody
Francis R. Cook
Don Cuddy
Ellaine Dickson
Enid Frankton
Colin Gaskell
Bill Gummer
Jeff Harrison
Linda Maltby
Jack Romanow
Doreen Watler
Ken Young

Those wishing to communicate with the Club should address correspondence to: The Ottawa Field-Naturalists' Club, Box 3264, Postal Station C, Ottawa, Canada K1Y 4J5. For information on Club activities telephone (613) 722-3050.

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Editor: Francis R. Cook, R.R. 3, North Augusta, Ontario K0G 1R0; 613-269-3211
Assistant to Editor: P.J. Narraway; **Copy Editor:** Wanda J. Cook
Business Manager: William J. Cody, Box 3264, Postal Station C, Ottawa, Ontario K1Y 4J5 (613) 996-1665
Book Review Editor: Dr. J. Wilson Eedy, R.R. 1, Moffat, Ontario L0P 1J0
Coordinator, *The Biological Flora of Canada*: Dr. George H. La Roi, Department of Botany, University of Alberta, Edmonton, Alberta T6G 2E9
Associate Editors:

C.D. Bird
Robert R. Campbell
Brian W. Coad
Anthony J. Erskine
W. Earl Godfrey
Diana Laubitz
William O. Pruitt, Jr.
Stephen M. Smith

Chairman, Publications Committee: Ronald E. Bedford

All manuscripts intended for publication should be addressed to the Editor at home address.

Subscriptions and Membership
Subscription rates for individuals are $23 per calendar year. Libraries and other institutions may subscribe at the rate of $38 per year (volume). The Ottawa Field-Naturalists' Club annual membership fee of $23 includes a subscription to *The Canadian Field-Naturalist.* All foreign subscribers (including USA) must add an additional $4.00 to cover postage. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be mailed to: The Ottawa Field-Naturalists' Club, Box 3264, Postal Station C, Ottawa, Canada K1Y4J5.
Second Class Mail Registration No. 0527 – Return Postage Guaranteed. Date of this issue: July-September 1992 (June 1993).

Back Numbers and Index
Most back numbers of this journal and its predecessors, Transactions of The Ottawa Field-Naturalists' Club, 1879-1886, and The Ottawa Naturalist, 1887-1919, and Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: Bendire's Thrasher, *Toxostoma bendirei*, Jasper National Park, Alberta, 30 May 1988, photographed by Alexander Mills. *See* note reporting the first confirmed Canadian record, pages 404–405.

MCZ
LIBRARY

The Canadian Field-Naturalist

JUN 30 1993

Volume 106, Number 3 July–September 1992

HARVARD
UNIVERSITY

Contributions to the Tardigrada of the Canadian High-Arctic 1. Freshwater Tardigrades from Devon Island, Northwest Territories

E. A. Van Rompu, W. H. De Smet and L. Beyens

Laboratorium voor Plant- en Dierkundige Algemene Biologie, Universiteit Antwerpen, R.U.C.A.-Campus Groenenborgerlaan 171, B-2020 Antwerpen, Belgium

Van Rompu, E. A., W. H. De Smet, and L. Beyens. 1992. Contributions to the Tardigrada of the Canadian High-Arctic 1. Freshwater tardigrades from Devon Island, Northwest Territories. Canadian Field-Naturalist 106(3): 303–310.

A list of thirteen species of Tardigrada from freshwater habitats on Devon Island (75°30'N) is given. The most frequently occurring species were *Isohypsibius granulifer*, *I. papillifer bulbosus* and *Hypsibius dujardini*.

Key Words: Tardigrada, High Arctic, Devon Island, Northwest Territories, Canada, freshwater.

In contrast to the European High Arctic and the Antarctic, Canadian High Arctic biota have hardly been investigated for their tardigrade fauna. Weglarska (1970) and Weglarska and Kuc (1980) studied moss-dwelling tardigrades sampled on Axel Heiberg Island, Northwest Territories (latitude 79°30'N) and listed 12 species and one forma of Heterotardigrada, and one species of Eutardigrada. The only other data available are by Ryan (1977) who reported *Pseudechiniscus* sp. and *Macrobiotus* sp. from Truelove Lowland on Devon Island.

It is clear from this limited number of studies that the primary question at the present stage of our knowledge is a basic one: which tardigrade species are living in the Canadian High Arctic and what is the composition of their assemblages as a function of environmental parameters.

The present paper deals with the tardigrade species found in a small number of samples from freshwater habitats, collected on Truelove and Sparbo-Hardy Lowlands, Devon Island.

Materials and Methods

Devon Island (75°30'N, 86°00'W) is part of the Canadian eastern High Arctic. Following Aleksandrova (1980), the island belongs to the north-eastern Canadian-northwestern Greenland subprovince of the arctic tundras. It has a tundra climate with mean annual temperature below freezing (-15°C to -18°C). The mean minimum and maximum temperatures for July are respectively 1.7°C and 7.2°C. The number of frost-free days varies from 30 to 40; mean annual precipitation ranges from 127 mm to 254 mm (Fletcher and Young s.d.). Microclimatological studies (Courtin and Labine 1977) show that the lowlands form some kind of a thermal oasis due to a higher summer radiation, the proximity of large bodies of water, föhn winds, etc. The physiographic controls give rise to a variety of microclimates.

Truelove and Sparbo-Hardy Lowland are situated on the northeastern coast (approximately 75°45'N and 84°00'W). According to Bliss (1977), these coastal lowlands result from postglacial rebound following deglaciation. During uplift, lagoons were cut off by raised beaches, resulting in the formation of shallow lakes. Some of the shallower lakes became infilled with lacustrine sediments to form meadows. There is an abundance of surface water resulting from blocked drainage by the raised beaches. This blockage gives rise to well developed sedge-moss meadows.

Sampling was carried out during the month of July 1987. Mosses were squeezed; plankton was taken with a plankton net. The tardigrades were fixed and preserved in 4% formalin. Tardigrades were found only in 6 of the 9 samples (4 moss, 1 epilithic-benthic, 4 plankton) examined.

List of tardigrade positive samples, site of collection and habitat description:

Truelove Lowland

Sample M 175: Pool, 25 × 30 m, depth 8 cm, water temperature 11.0°C, pH 8.07, conductivity 275 µS cm^{-1}, transparency (Weigelt) 20 cm, total hardness > 7°d < 14°d. 09.07.1987. Nature of sample : moss (*Drepanocladus lycopodioides* (Brid.) Warnst).

Sample M 185: Pool, water temperature 8.0°C, pH 7.28, conductivity 145 µS cm^{-1}, transparency

32.5 cm, total hardness > 4°d < 7°d. 11.07.1987. Nature of sample: moss (*Calliergon richardsonii* (Mitt.) Kindb).

Sample M 191: See M 175. Nature of sample: epilithic-benthic material.

Sample M 198: Pool, moderately large, depth 10-20 cm, pH 6.91, conductivity 42 μS cm^{-1}. 10.07.1987. Nature of sample : submerged mosses.

Sample W 203: Pool, moderately large, depth 20cm, water temperature 12.0°C, pH 8.15, conductivity 205 μS cm^{-1}, transparency 21.5 cm, total hardness > 7°d< 14°d. 12.07.1987. Nature of sample: plankton.

Sparbo-Hardy Lowland

Sample M 235: Lakelet, depth 0.5m+, water temperature 8.0°C, pH 8.30, conductivity 190 μS cm^{-1}, total hardness > 4 °d < 7°d. 16.07.1987. Nature of sample: moss (*Scorpidium scorpioides* (Hedw.) Limpr.).

List of species

Nomenclature follows Ramazzotti and Maucci (1983) with minor modifications. General zoogeographical and ecological remarks were taken from Ramazzotti and Maucci (1983) and Dastych (1988). The number of specimens found is bracketed.

HETEROTARDIGRADA

Family Echiniscidae

Echiniscus spitsbergensis Scourfield, 1897 (Figure 1. 1a-g)

A series of two clawed larvae, juvenile stages with four claws on each leg, and sexually mature animals with one or two eggs.

The cuticle is characteristically sculptured and consists of penta- or hexagonal depressions surrounded by an irregular wrinkled wall. Our specimens show two dorsal appendages, a filiform C^d and a long jag or spine at D^d; lateral filiform appendages present at A, C and D; between dorsal and lateral appendages a small jag at C' and at D'; B is lacking and E consists of a row of spines with up to 4 or 5 jags. All specimens, even the larvae, have spine E developed and all specimens lack appendage B, even the sexually mature ones (*spinuloides* type). The absence of specimens with filiform appendage B developed could be due to the fact that most of them had not yet reached full morphological adult stage. For specimens from Greenland, Petersen (1951) also noted that this feature was lacking even in the very large (320 μm) and the sexually mature ones, which demonstrates that this character may be absent altogether. According to Dastych (1988) this species is a boreal-mountain subelement with holarctic range. The species was reported in large numbers by Weglarska and Kuc (1980) from 57 stations, and among different mosses on Axel Heiberg Island.

Dimensions: body length: 227-393 μm; egg: 46 × 61 μm.

Samples: M 191 (4), M 198 (10).

Pseudechiniscus suillus (Ehrenberg, 1853) (Figure 1. 2)

All features of the specimen conform with the description of the forma *facettalis* Petersen, 1951. Small animal, cuticle with a fine regular granulation. The head plate and the terminal plate show distinct facetting. In addition to the lateral facetting of the terminal plate, there is a weakly facetted triangle in the middle. Cosmopolitan. *P. suillus* f. *facettalis* has been reported in large numbers from six localities on Axel Heiberg Island by Weglarska and Kuc (1980).

Dimensions: body length: 123-177 μm.

Samples: M 198 (5), M 235 (2).

EUTARDIGRADA

Family Amphibolidae

Amphibolus weglarskae (Dastych, 1972) (Figure 1. 3a-d)

Robust animals with yellow-brownish pigment and two eye spots. Mouth cavity with 14 lamellae. Pharyngeal tube broad and straight; oval bulbus with three macroplacoids, the two first so closely fused together, as to resemble one long macroplacoid with a distinct incision in the middle; the top ends narrowing and almost reaching the apophyses. The third macroplacoid frequently with a flat broadening at the end. Doubleclaws of the *Amphibolus* type with distinct lunulae which are largest and mostly crenulated in external claw of leg IV. Cold-stenothermic and hygrophilous. Distribution still insufficiently known (British Columbia (Canada), Tatra Mountains in Poland, Italy, Norway, Greenland, Svalbard). On the basis of the present findings we are inclined to consider *A. weglarskae* as an arctic-boreo-alpine element.

Dimensions: body length: 386 μm; bulbus length: 55 μm, diameter: 49 μm; pharyngeal tube length: 68 μm, diameter: 8 μm.

Sample : M 235 (1).

Family Hypsibiidae

Diphascon recamieri Richters, 1911 (Figure 2. 1a-e).

Animals of medium size. Very long pharyngeal tube; the drop-like structure on the buccopharyngeal tube was absent in the specimens studied. Elongated bulbus with 2 macroplacoids; the first (almost twice as long as the second) is divided in two, the first halves somewhat smaller and thinner. Microplacoid and distinct septulum present (cf. Weglarska 1959). Petersen (1951) and Kathman (1990) did not find specimens with septula in Greenland. An arctic-alpine subelement with holarctic distribution.

Dimensions: body length: 163-299 μm; bulbus (specimen of 299 μm) length: 37 μm, diameter: 19 μm; pharyngeal tube (specimen of 299 μm) length: 77 μm, diameter: 1 μm.

Sample : M 185 (2).

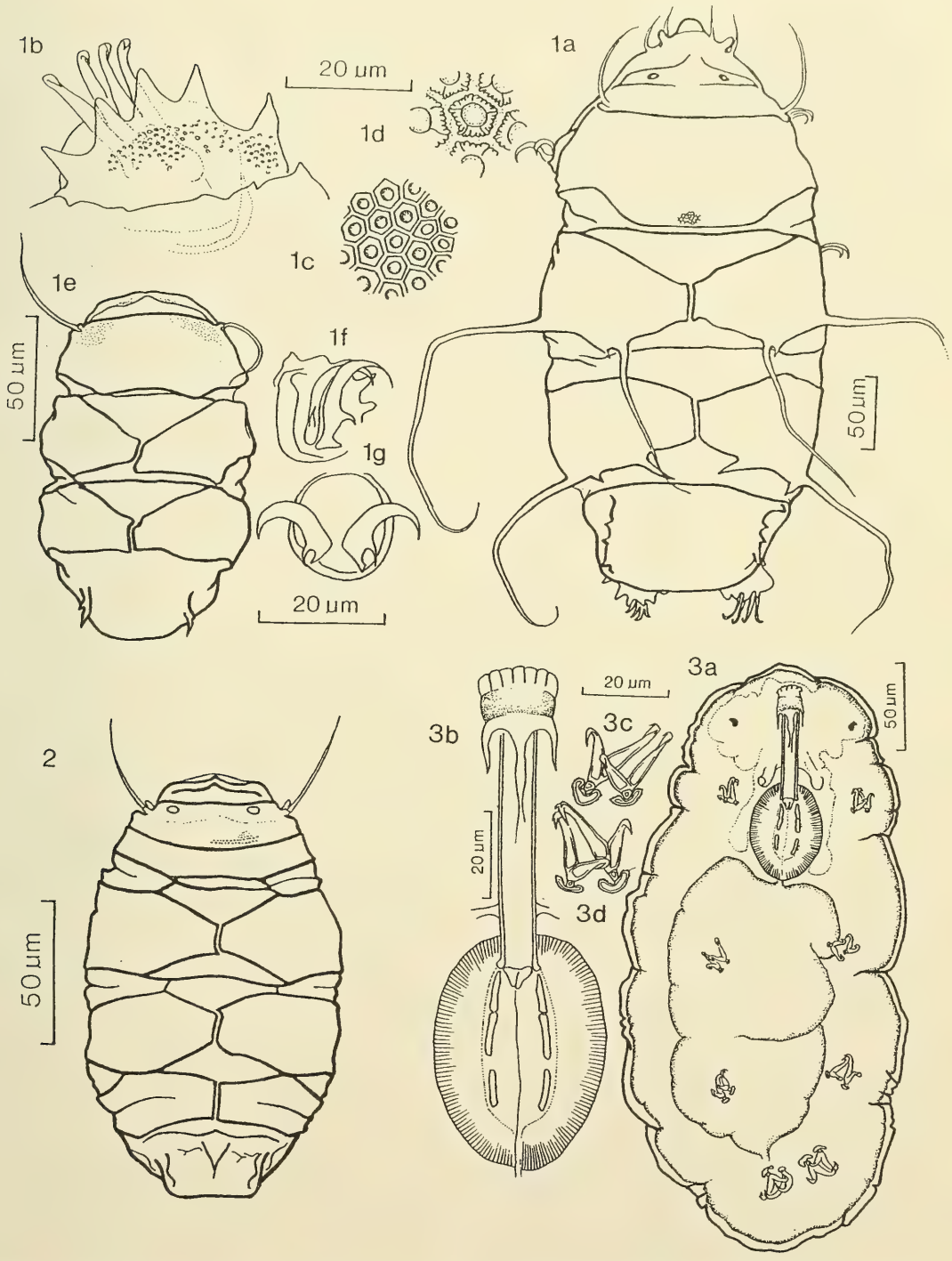


FIGURE 1. 1 *Echiniscus spitsbergensis*: a general view, b claws of leg IV, c cuticle, d detail of cuticle, e juvenile stage, f claws of juvenile leg III, g claws of juvenile leg IV; 2 *Pseudechiniscus suillus*: general view; 3 *Amphibolus weglarskae*: a general view, b buccal apparatus, c, d claws of leg IV.

Hypsibius convergens (Urbanowicz, 1925) (Figure 2. 2a-c)

Hyaline animals. Ovoid bulbus with two broad macroplacoids, the first longer than the second and mostly with an incision in the middle; the second thick and broad with rounded corners. No microplacoid. Doubleclaws resembling those of *Hypsibius dujardini*; sclerotized bars between doubleclaws absent. An euryhygric and cosmopolitan species.

Dimensions: body length: 115-213 μm; bulbus (specimen of 200 μm) length: 22 μm, diameter: 18 μm; pharyngeal tube (specimen of 200 μm) length: 31 μm, diameter: 2 μm.

Samples : M 175 (2), M 191 (10).

Hypsibius dujardini (Doyère, 1840) (Figure 2. 3).

Hyaline animals. Oval bulbus with two long macroplacoids and large distinct microplacoids. First macroplacoid longer and constricted in the middle. Doubleclaws typical for the species. A hygrophilous and cosmopolitan species.

Dimensions : body length: 109-269μm; bulbus (specimen of 194 μm) length: 26 μm, diameter: 20 μm; pharyngeal tube (specimen of 194 μm) length: 29 μm, diameter: 2 μm.

Samples : M 185 (4), M 191 (5), M 198 (6), M 235 (1).

Isohypsibius cf. *canadensis* (Murray, 1910) (Figure 2. 4a-b)

Small animal. Almost spherical bulbus. Three macroplacoids, increasing in size from the first to the third. At one side of the bulbus the two first macroplacoids are fused together, showing a distinct incision in the middle. No microplacoid. Doubleclaws slender, the branches united near their basis; interior and exterior claw not much different in size. North American species (Vancouver Island, Canada; Virginia; California).

Dimensions: body length: 112 μm; bulbus length: 15 μm, diameter: 12 μm; pharyngeal tube length: 20 μm, diameter: 3 μm.

Sample: M 175 (1).

Isohypsibius granulifer Thulin, 1928 (Figure 2. 5a-f).

Animals covered with tubercles varying in size from small granules to distinct rounded papillae, increasingly pronounced posteriorally. Bulbus short oval with three macroplacoids; the first two macroplacoids almost equal in size, in most cases close together, the third longer than the first two. A connection may be present between the second and third macroplacoid. Big and strong doubleclaws; the two branches of each doubleclaw can be moved to a nearly horizontal position. Hydrophilous and cosmopolitan.

Dimensions: body length: 116-191 μm; bulbus (specimen 139 μm) length: 20 μm, diameter: 15 μm; pharyngeal tube (specimen 139 μm) length: 26 μm, diameter: 1 μm.

Samples: M 175 (1), M 191 (7), M 198 (10), W 203 (1), M 235 (1).

Isohypsibius papillifer bulbosus (Marcus, 1928) (Figure 3. 1a-d)

Animals covered with large papillae, each showing a broad hemispherical swelling at its base and a conical process with c. 4 stiff hairs at its top. The papillae are arranged in transverse and longitudinal rows. Transverse rows anterior to third pair of legs with six papillae, posteriorly with four papillae. Swellings of processes more pronounced dorsally than laterally. Small, rounded tubercles, without conical processes and hairs, between the bases of the papillae. At each side of the head, two small, lateral processes, placed closely together. Base of fourth pair of legs with large hemispherical swelling. Bulbus oval with three macroplacoids increasing in size from the first to the third. The first two macroplacoids mostly closely together. No microplacoid. Internal and external claw of doubleclaws not very different in shape and length. Hygrophilous and cosmopolitan.

Dimensions: body length: 96-146 μm; bulbus (specimen 146 μm) length: 19 μm, diameter: 14 μm; pharyngeal tube (specimen 146 μm) length: 22 μm, diameter: 1 μm. Eggs: 38 × 24 μm.

Samples: M 175 (1), M 185 (3), M 191 (2), M 235 (4).

Isohypsibius schaudinni (Richters, 1909) (Figure 3. 2a-b)

Hyaline animals with a bulbus typical for the species. The three macroplacoids increasing in size from first to third and evenly spaced. Microplacoid present. Mouth cavity situated ventrally. Internal and external claw of doubleclaw not very different in size and shape. Euryhygric and cosmopolitan.

Dimensions: body length: 111 μm; bulbus length: 16 μm, diameter: 14 μm; pharyngeal tube length: 18 μm, diameter: 1 μm.

Sample: M 175 (1).

Isohypsibius tetradactyloides (Richters, 1907) (Figure 3. 3a-d)

Hyaline animal. Ovoid bulbus with three macroplacoids, baton-shaped and increasing in length from the first to the third. Internal and external claw of doubleclaws not very different in size and shape. A hygrophilous species with cosmopolitan distribution.

Dimensions: body length: 175 μm; bulbus length: 28 μm, diameter: 25 μm; pharyngeal tube length: 35 μm, diameter: 3 μm.

Sample: M 185 (1).

Family Macrobiotidae

Macrobiotus dianeae Kristensen, 1982 (Figure 3. 4a-d)

Hyaline animals showing the typical features of the species. Mouth cavity with 10-12 lamellae. Oval bulbus with three macroplacoids, the first two closely together and the third with a typical broadening at its

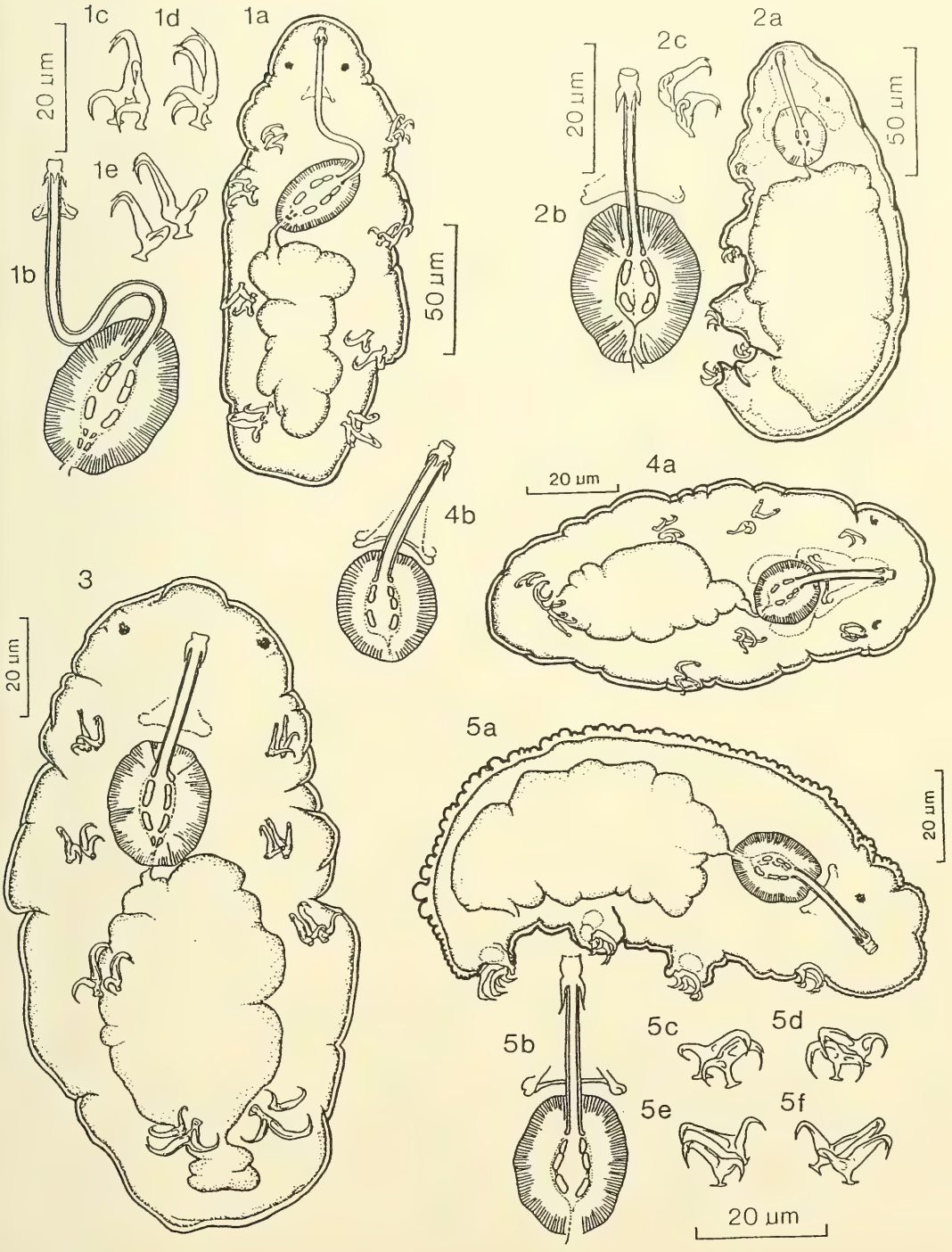


FIGURE 2. 1 *Diphascon recamieri*: a general view, b buccal apparatus, c claws of leg II, d claws of leg III, e claws of leg IV; 2 *Hypsibius convergens*: a general view, b buccal apparatus, c claws of leg IV; 3 *Hypsibius dujardini*: general view; 4 *Isohypsibius* cf. *canadensis*: a general view, b buccal apparatus; 5 *Isohypsibius granulifer*: a general view, b buccal apparatus, c claws of leg I, d claws of leg II, e claws of leg III, f claws of leg IV.

posterior extremity; the third 2/3 length of the first two. Doubleclaws of the *echinogenitus* type. The species was described from a warm homothermic spring on Disko Island, West Greenland by Kristensen (1982). We (unpublished) found *M. dianeae* in aquatic habitats from W. Greenland, Little Cornwallis Island (Northwest Territories, Canada) and Tanzania (Kilimanjaro). We tentatively place it amongst the hydrophilous arctic-alpine elements.

Dimensions: body length: 210-340 μm; bulbus (specimen of 319μm) length: 46 μm, diameter: 36 μm; pharyngeal tube (specimen of 319 μm) length: 56 μm, diameter: 6 μm.

Samples: M 185 (1), M 235 (7).

Dactylobiotus dispar (Murray, 1907) (Figure 3. 5a-d)

Large animals with distinct eye spots. Cuticle with fine granulation. Broad oval bulbus; two macroplacoids, the first twice as long as the second and constricted in the middle. The macroplacoids are connected with a ligament. Big doubleclaws each with two chitinous bars between, touching only at the base of the claw. Primary branches long and slender with two accessory spines. All specimens found displayed a dorso-lateral hump symmetrically on either side of the middle line. A hydrophilous and cosmopolitan element.

Dimensions: body length: 329-497μm; bulbus (specimen of 497 μm) length: 70 μm, diameter: 47 μm; pharyngeal tube (specimen of 497 μm) length: 73 μm, diameter: 8 μm.

Sample: M 185 (3).

Discussion

Thirteen tardigrade species have been found in plankton (1), moss (13), and benthic-epilithic material (5) from aquatic habitats. The species richness was rather low and varied from 4 to 6 for the vegetation and epilithic-benthic samples; the plankton contained one species. The occurrence of tardigrades at very low densities in plankton of shallow arctic waters is not uncommon (De Smet et al. 1987, 1988; Van Rompu & De Smet 1988, 1991) and has been attributed to convective and wind mixing. The numerical abundance of tardigrades was low and varied from 1 to 31 individuals. The most frequently encountered species were *Isohypsibius granulifer, I. papillifer bulbosus* and *Hypsibius dujardini*. These taxa, together with *Macrobiotus dianeae*, are known to be the most frequently occurring and numerically dominant tardigrade species in submerged vegetation from the High Arctic (Van Rompu and De Smet 1991).

The majority of the species found have a cosmopolitan (Dastych 1988) distribution (*Echiniscus suillus, Hypsibius convergens, H. dujardini, Isohypsibius granulifer, I. papillifer bulbosus, I. schaudinni, I. tetradactyloides, Dactylobiotus dispar). Isohypsibius canadensis* appears to be a North American element. The remainder of the species (*Echiniscus spitsbergensis, Amphibolus weglarskae, Diphascon recamieri, Macrobiotus dianeae*) have an arctic-boreo-alpine distribution.

Acknowledgments

We wish to thank Mr. P. De Bock for the identification of the mosses. Mrs. R. Pype typed the manuscript and Prof. Dr. D. K. Ferguson corrected the English text. One of us (L. B.) received a grant from the National Foundation for Scientific Research.

Literature Cited

Aleksandrova, V. D. 1980. The Arctic and Antarctic: their division into geobotanical areas. Cambridge University Press, Cambridge. 247 pages.

Bliss, L. C. 1977. Introduction. Pages 1–11 *in* Truelove Lowland, Devon Island, Canada: A high arctic ecosystem. *Edited by* L. C. Bliss. The University of Alberta Press, Edmonton. 714 pages.

Courtin, G. M., and **C. L. Labine.** 1977. Microclimatological studies on Truelove Lowland. Pages 73–106 *in* Truelove Lowland, Devon Island, Canada: a high arctic ecosystem. *Edited by* L. C. Bliss. The University of Alberta Press, Edmonton. 714 pages.

Dastych, H. 1988. The Tardigrada of Poland. Monografie Fauny Polski 16. 255 pages, 31 plates.

De Smet, W. H., E. A. Van Rompu, and **L. Beyens.** 1987. Rotifera, Gastrotricha en Tardigrada uit Shetland, de Faroër en Spitsbergen. Natuurwetenschappelijk Tijdschrift 69: 81–102.

De Smet, W. H., E. A. Van Rompu, and **L. Beyens.** 1988. Contribution to the rotifers and aquatic Tardigrada of Edgeøya (Svalbard). Fauna norvegica Series A 9: 19–30.

Fletcher, R. J., and **G. S. Young.** (sine dato). Climate of Arctic Canada in Maps. Boreal Institute for Northern Studies, Occasional Publication Number 13.

Kristensen, R. M. 1982. New aberrant eutardigrades from homothermic springs on Disko Island, West Greenland. Pages 203–220 *in* Proceedings of the Third International Symposium on the Tardigrada, August 3-6, 1980, Johnson City, Tennessee.

Petersen, B. 1951. The tardigrade fauna of Greenland. A faunistic study with some few ecological remarks. Meddelelser om Grønland 150(5): 1–94.

Ramazotti, G., and **W. Maucci.** 1983. II Philum Tardigrada. III edizione riveduta e aggiornata. Memorie dell' Istituto Italiano di Idrobiologia Dott. Marco De Marchi 41: 1–1012.

Ryan, J. 1977. Invertebrates of Truelove Lowland. Pages 699–703 *in* Truelove Lowland, Devon Island, Canada: a high arctic ecosystem. *Edited by* L. C. Bliss. The University of Alberta Press, Edmonton. 714 pages.

Van Rompu, E. A., and **W. H. De Smet.** 1988. Some aquatic Tardigrada from Bjørnøya (Svalbard). Fauna norvegica Series A 9: 31–36.

Van Rompu, E. A., and **W. H. De Smet.** 1991. Contribution to the freshwater Tardigrada from Barentsøya, Svalbard (78°30'N). Fauna norvegica Series A 12: 29–39.

Weglarska, B. 1959. Tardigraden Polens. II. Teil. Acta Societatis Zoologicae Bohemoslovenicae 23: 354–357.

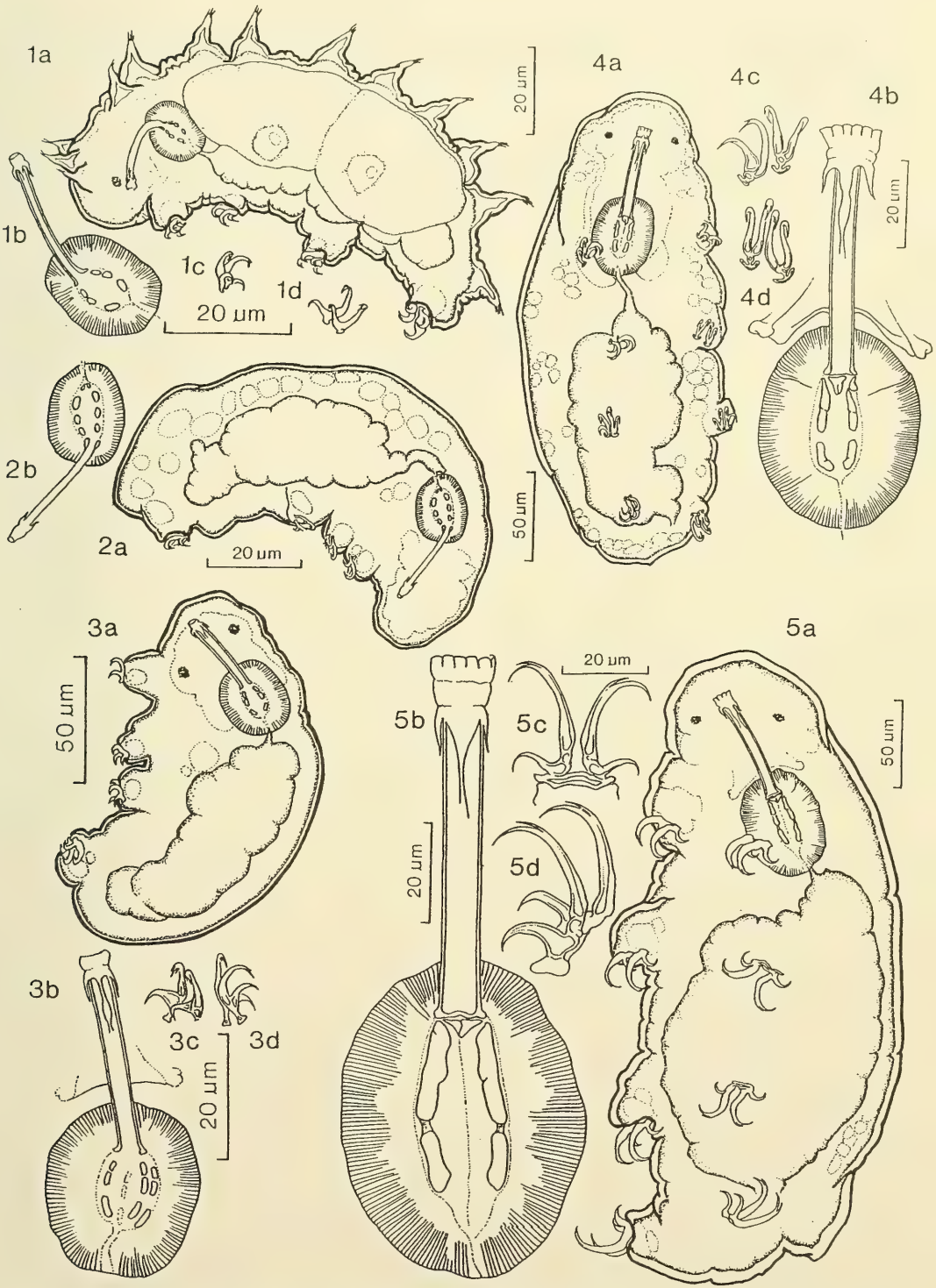


FIGURE 3. 1 *Isohypsibius papillifer bulbosus*: a general view, b buccal apparatus, c claws of leg III, d claws of leg IV; 2 *Isohypsibius schaudinni*: a general view, b buccal apparatus; 3 *Isohypsibius tetradactyloides*: a general view, b buccal apparatus, c claws of leg III, d claws of leg IV; 4 *Macrobiotus dianeae*: a general view, b buccal apparatus, c claws of leg III, d claws of leg IV; 5 *Dactylobiotus dispar*: a general view, b buccal apparatus, c claws of leg II, d claws of leg IV.

Weglarska, B. 1970. *Hypsibius (Isohypsibius) smereczynskii* spec. nov., a new species of fresh-water tardigrade. Zeszyty Naukowe Uniwersytetu Jagiellońskiego, Prace Zoologiczne 16: 107–114, 3 plates.

Weglarska, B., and **M. Kuc.** 1980. Heterotardigrada from Axel Heiberg Island. Zeszyty Naukowe Uniwersytetu Jagiellońskiego, Prace Zoologiczne 26: 53–66.

Received 14 June 1991
Accepted 31 March 1992

Range Extension for the Plains Spadefoot, *Scaphiopus bombifrons*, Inferred from Owl Pellets Found near Outlook, Saskatchewan

RICHARD E. MORLAN[1] and JOHN V. MATTHEWS, JR.[2]

[1]Archaeological Survey of Canada, Canadian Museum of Civilization, Hull, Québec J8X 4H2
[2]Terrain Sciences Division, Geological Survey of Canada, Ottawa, Ontario K1A 0E8

Morlan, Richard E., and John V. Matthews, Jr. 1992. Range extension for the Plains Spadefoot, *Scaphiopus bombifrons*, inferred from owl pellets found near Outlook, Saskatchewan. Canadian Field-Naturalist 106(3): 311–315.

Owl pellets found near Outlook, Saskatchewan, contain Plains Spadefoot (*Scaphiopus bombifrons*) bones approximately 50 km north of the documented range of this species. We suggest that spadefoots are living in an area of parabolic dunes and blowouts just south of Outlook and that similar sand hill areas near Saskatoon should be searched for owl pellets that might contain similar remains. Given the elusive habits of the spadefoot, owl pellet analysis may provide an important method of recording their presence.

Key Words: Plains Spadefoot, *Scaphiopus bombifrons*, range extension, owl pellets, Outlook, Saskatchewan.

Many birds rid themselves of the indigestible parts of their food by regurgitating pellets. The pellets are usually comprised of fur, feathers, bones and other hard parts of vertebrates, as well as the exoskeletons of invertebrates (Terres 1980: 683-684). Analysis of pellet contents plays important roles in revealing the food habits of birds and in paleoenvironmental studies of archaeological and paleontological sites (*see* Kusmer 1990, with references).

This paper reports an analysis of four pellets whose contents suggest both a range extension for the Plains Spadefoot (*Scaphiopus bombifrons*) and a list of insects that may reflect aspects of spadefoot diet. In turn, the spadefoot is one of eight vertebrate species that comprise the diet of a pellet-producing raptor, inferred to be an owl.

Methods and Materials

The pellets were collected from the surface of the Sjovold archaeological site, near Outlook, Saskatchewan, in July 1990. The site excavator, Ian Dyck, Curator of Plains Archaeology, Canadian Museum of Civilization, had repeatedly observed three owls roosting on the stream bank at the collection site. From his description of their size and colour, the birds included a pair of adult Great Horned Owls (*Bubo virginianus*) accompanied by a smaller fledgling. Dyck's observations encouraged R. E. M. to search the area for pellets that would contain the remains of local small vertebrates.

The pellets lay on the surface of the 5 m high stream bank where they had been lightly splashed with silt during a recent rainstorm. When picked apart in the laboratory, the pellets were found to be comprised primarily of rodent hair that showed no sign of degradation. Hence the pellets cannot have been previously buried and eroded from the archaeological site. Their modern age is confirmed by remains of the recently introduced house mouse in one of them and an introduced species of weevil in all of them. We emphasize this point to show that the inferred extension of spadefoot range refers to the modern population rather than to a prehistoric extralimital occurrence that might reflect past environmental changes.

The pellets were numbered (1–4) and measured. The largest, number 2, measured 5.0 cm in length and 2.5 cm in diameter. Each of the others measured approximately 3.0 cm by 1.5 cm. Bones, insects, and seeds were manually picked from the mass of hair under low magnification. After removing the largest objects, the pellets were soaked in a commercial depillatory; the residue was washed in denatured alcohol, dried, and examined again for smaller items.

Results

The pellets produced a few seeds as well as larger assemblages of insects and vertebrates. The seeds represent grasses (cf. *Panicum* sp. from pellets 2 and 3; *Triticum* sp. from pellet 4) and a cactus (cf. *Coryphantha* sp. from pellet 2).

Insects recovered from the pellets are listed in Table 1 by pellet number. All of these insects live now on the central Canadian prairies as well as in open sites within the mixed wood zone. All of the pellets contain numerous heads, elytra and pronota of the widely distributed, introduced weevil *Otiorhynchus ovatus* which lives on the ground and is active at night when it ascends food plants (Emenegger and Berry 1978; Warner 1976). Ant heads also occur in all of the pellets, although they are much rarer than *Otiorhynchus* parts. The head capsule of *Geopinus* contains a nearly complete ant. The ground beetle *Amara quenseli*, a xerophilus species living on exposed somewhat sandy soils, sometimes around the shores of inland lakes

TABLE 1. Insect remains found in four owl pellets from the Sjovold site, Saskatchewan.

Taxon	Pellet: No. 1	No. 2	No. 3	No. 4
Phylum Arthropoda				
Class Insecta				
Order Orthoptera (grasshoppers, etc.)				
Family Acrididae	+	–	–	+
Order Coleoptera (beetles)				
Family Carabidae (ground beetles)				
Amara quenseli Schonh.	+	+	+	+
Amara (s. str.) sp.	+	–	–	–
Amara sp.	–	–	+	–
Piosoma setosum LeC.	+	–	–	–
Harpalus (Pseudophonus) sp.	+	–	–	–
Harpalus amputatus Say	+	–	–	–
Geopinus incrassatus Dej.	+	–	–	–
Lebia vittata F.	+	–	–	–
Cymindis planipennis Lec.	–	+	+	+
Family Hydrophilidae (water scavenging beetles)				
Genus?	+	–	–	–
Family Elmidae Genus	?	–	–	–
Family Elateridae (click beetles)				
Genus?	+	–	–	–
Family Tenebrionidae (darkling beetles)				
Genus 1	–	+	+	–
Genus 2	+	–	–	–
Family Coccinellidae (ladybird beetles)				
Genus?	+	–	–	–
Family Curculionidae (weevils)				
Otiorhynchus ovatus (L.)[a]	+	+	+	+
Order Lepidoptera (butterflies, moths)				
Family Sphingidae				
Sphinx gordius Cramer[b]	–	+	+	+
Order Hymenoptera (wasps, ants)				
Family Formicidae (ants)				
Genus? *Myrmica* type	cf	–	–	–
Genus? *Formica* type	+	+	+	+

[a]identified by R. Anderson, Canadian Museum of Nature.
[b]identified by J. D. Lafontaine, Agriculture Canada.

(Lindroth 1968), occurs as heads, pronota and elytral fragments in all four pellets.

Although pellet 1 contains the greatest variety of insects, it alone lacks lepidopteran larval fragments and identifiable fragments of the ground beetle *Cymindis planipennis*. The latter inhabits dry sites, often being found in gravel pits in central Canada (Lindroth 1968). Pellet 2 contains well preserved fragments of three individuals representing at least one female and one male. The tenebrionid beetle fragments found in pellet 1 represent a different genus than those in pellets 2 and 3. All of the ground beetles in pellet 1 are typical of dry sites. One of them, *Lebia vittata*, is associated with goldenrod (*Solidago*), three species of which are known in the site area (Abouguendia et al. 1981).

Larval fragments of the Sphinx Moth (*Sphinx gordius*) occur in pellets 2–4. The larvae feed on trees but descend to the ground in late summer before pupating. All of the larval mandibles recovered from the pellets represent the last instar which would be encountered on the ground by a vertebrate predator (J. D. Lafontaine, personal communication).

Vertebrate remains recovered from the pellets are listed in Table 2. Spadefoot and rodent bones occur in all four pellets with spadefoot predominant in pellet 1 and rodents predominant in the other three. The frequencies per pellet in Table 2 refer to the number of identified specimens (NISP), and the category "small rodents" represents the post-cranial remains of the five taxa of small rodents that are identified from their cheek teeth. Since the remains of a given individual vertebrate may well be preserved in more than one pellet, it is pointless to calculate the minimum number of individuals (MNI) represented in each pellet. However, MNI counts are provided for the total assemblage.

The Tiger Salamander (*Ambystoma tigrinum*) occurs throughout the grassland and aspen parkland of Saskatchewan (Cook 1978, 1984). It eats insects

TABLE 2. Vertebrate remains found in four owl pellets from the Sjovold site, Saskatchewan.[a]

Taxon	Pellet: No. 1	No. 2	No. 3	No. 4	MNI[b]
Phylum Vertebrata					
Class Amphibia					
Order Urodela					
Family Ambystomidae					
Ambystoma tigrinum	–	31	–	3	2
Order Anura					
Family Pelobatidae					
Scaphiopus bombifrons	291	88	2	21	8
Class Mammalia					
Order Rodentia					
Family? (small rodents)	125	995	194[c]	398	
Family Sciuridae					
Spermophilus sp.	–	–	–	1	1
Family Heteromyidae					
Perognathus fasciatus	–	21	3	22	7
Family Cricetidae					
Genus?	–	3	–	–	–
Peromyscus sp.	–	12	6	1	5
Onychomys leucogaster	1	22	12	10	9
Family Arvicolidae					
Microtus pennsylvanicus	–	–	–	1	1
Family Muridae					
Mus musculus	6	–	–	–	3

[a]Frequencies per pellet refer to the number of identifiable specimens.
[b]MNI (minimum number of individual) counts are provided for the total assemblage.
[c]Small rodent ribs and podials were not picked from Pellet 3.

and other invertebrates and is active on the surface during and after heavy rains, especially at night. The Plains Spadefoot (*Scaphiopus bombifrons*) is known from southwestern Saskatchewan with northern records at Alsask and Elbow (Nero 1959; Cook 1978: 8). The Sjovold site, where the pellets were collected, is located approximately 50 km northwest of Elbow on the left (west) bank of the South Saskatchewan River. Spadefoots are adapted to arid conditions and may spend long dry periods underground, emerging at night after a heavy rain to breed and forage for insects (Cook 1984: 60).

Data on rodent diet and habit may be found in Banfield (1974). The Olive-backed Pocket Mouse (*Perognathus fasciatus*) lives in loose sandy soils on arid grasslands, eating primarily weed seeds but also some insects, especially during the early summer, and always at night. The *Peromyscus* remains found in the pellets probably represent the deer mouse (*P. maniculatus*), a mainly nocturnal seed-eater. The Grasshopper Mouse (*Onychomys leucogaster*) is highly carnivorous, living primarily on insects, and is chiefly nocturnal. Meadow Voles (*Microtus pennsylvanicus*) are most active just after dawn and just before dusk, and they live primarily on the stems of grasses, sedges, and forbs. The introduced House Mouse (*Mus musculus*) is chiefly nocturnal and lives on seeds, fruits and plant stems.

Discussion

Although we did not observe the birds directly, several characteristics of the pellets indicate that they were cast by one or more owls. The pattern of anatomical representation in the pellet contents, the breakage pattern exhibited by the bones, and the limited evidence of digestion on the bones all match the taphonomic signature of owl pellets as distinct from hawk pellets and mammalian carnivore scats (*see* Dodson and Wexlar 1979; Hofman 1988; Kusmer 1990).

Furthermore, most of the vertebrates and invertebrates represented in the pellets are nocturnal. Dyck saw owls both sitting at and flying from the collection site only the day before the pellets were collected, but we cannot be certain that the pellets were cast at that time. Dyck consulted the landowner, Oscar Sjovold, a former patrol officer with the Saskatchewan Department of Natural Resources, who reported having seen Great Horned Owls repeatedly at the collection site.

Except for the Meadow Vole and ground squirrel, each represented by a single element, the vertebrate prey species are chiefly or strictly nocturnal. Likewise the insects are predominantly nocturnal. All species of *Otiorhynchus* are nocturnal (Warner 1976) as is the ground beetle *Amara quenseli. Piosoma,* many of the species in the *Harpalus*

(Pseudophonus) group, and *Geopinus incrassatus* have been collected at lights and therefore are probably active at night. However, very little is known about the circadian rhythms of *Lebia vittata, Harpalus amputatus* and *Amara* (s.str.); these species are very active in bright sunshine, so it would be surprising if they were also active at night. Obviously diurnal insects in this assemblage could have been consumed by chiefly nocturnal rodents that exhibit some daytime or crepuscular activity.

The relative proportions of insects and vertebrates among the pellets may indicate who was eating whom. The greatest variety of insects occurs in pellet 1 where the Plains Spadefoot is predominant among the vertebrates and is accompanied by the seed-eating House Mouse. The insects in pellet 1 might even be considered a spadefoot menu. The insect taxa found only in the other pellets (sphingid, *Cymindis,* and a tenebrionid) might be explained by the prevalence of Grasshopper Mouse remains in those pellets. Having traced the food chain this far, we note that the presence of an ant in the head capsule of *Geopinus* suggests that the beetle was already dead and was being scavenged by the ant when ingested by a vertebrate, probably the spadefoot. Remarkably, all of these steps in the food chain have been preserved despite digestion by the owls.

Given the strong flight capabilities of owls, we must consider whether the animals obtained in these pellets were locally obtained. Perhaps owls hunting near Elbow, within the documented range of the Plains Spadefoot, could fly to the Sjovold site before casting pellets. With a meal-to-pellet interval of as much as 12 hours (Terres 1980: 684), the 50 km distance does not seem too great. However, if the pellets were cast by the owls observed by Dyck, the presence of a growing fledgling with two adults argues against such commuting and suggests that these owls were on their home range.

Assuming, then, that the spadefoots were obtained in the site vicinity, it is worth speculating on the location of suitable habitat. The left (west) bank of the river, where the Sjovold site is located, offers little or no suitable habitat for spadefoots or for several of the prey species, but an area of parabolic dunes and blowouts directly across the river just south of Outlook (Scott 1971: Map 1249A) offers ideal habitat for animals adapted to arid, sandy soils (spadefoot, pocket mouse, and many of the insects).

If Plains Spadefoots live near Outlook, why have herpetologists not recorded them there? The answer may lie in spadefoot habits. In documenting Plains Spadefoot range in Manitoba, Preston and Hatch (1986) experienced many failed attempts to encounter these animals directly. Spadefoots, "due to their nocturnal habits and their propensity for breeding only after heavy rain ... and sufficiently high temperatures (10°C), are not often seen by the casual observer" (Preston and Hatch 1986: 123). Indeed some species of *Scaphiopus,* although not necessarily *S. bombifrons,* are able to consume enough food in one outing on the surface to provide energy stores for more than a year (Dimmitt and Ruibal 1980).

To record the full extent of spadefoot range, it may be worthwhile to pay more attention to the indefatigible owls. Hunting at night after a heavy rain, the owls are perhaps best able to encounter spadefoots on the surface and to leave on the surface evidence of spadefoot presence in the form of pellet contents. There are extensive tracts of dunes and blowouts, locally known as sand hills, near Saskatoon (Epp 1983: 185). To find spadefoots there would extend the range in Saskatchewan to the latitude already recorded in Alberta where living Plains Spadefoots have been discovered in Dilberry Lake Provincial Park (J. W. Wolford, personal communication to F. R. Cook). Post-glacial fossils have also been found near Killam at 52°48'N lat. (Bayrock 1967). Their presence near Saskatoon would help to explain the discovery of a spadefoot bone in a nearby archaeological deposit only 945 years old (Morlan 1991).

Acknowledgments

We thank Ian Dyck and Oscar Sjovold for sharing their observations concerning the owls; Francis R. Cook for encouragement to prepare this paper; Darlene Balkwill, Canadian Museum of Nature (CMN), for the loan of a spadefoot skeleton she had borrowed from the Royal Ontario Museum; the Herpetology and Mammalogy Sections, Vertebrate Zoology Division, CMN, for loans of other vertebrate skeletons; and Robert Anderson (CMN) and and J. D. Lafontaine (Agriculture Canada) for identification of certain insect fragments.

Literature Cited

Abouguendia, Z., R. Godwin, L. Baschak, and **S. Lamont**. 1981. Flora and vegetation of the Sjovold archaeological site (Suicide Coulee) area. Saskatchewan Research Council Publication Number C-805-10-E-81.

Banfield, A. W. F. 1974. The Mammals of Canada. University of Toronto Press, Toronto. 438 pages.

Bayrock, L. A. 1967. Fossil *Scaphiopus* and *Bufo* in Alberta. Journal of Paleontology 38(6): 1111–1112.

Cook. F. R. 1978. Amphibians and reptiles of Saskatchewan. Saskatchewan Museum of Natural History Popular Series 13. 28 pages. (Reprint of 1966 edition).

Cook, F. R. 1984. Introduction to Canadian Amphibians and Reptiles. National Museums of Canada, Ottawa. 200 pages.

Dimmitt, M. A., and **R. Ruibal.** 1980. Exploitation of food resources by spadefoot toads (*Scaphiopus).* Copeia 1980(4): 854–862.

Dodson, P., and **D. Wexlar**. 1979. Taphonomic investigations of owl pellets. Paleobiology 5(3): 275–284.

Emenegger, D. B., and **R. E. Berry.** 1978. Biology of strawberry root weevil on peppermint in western Oregon. Environmental Entomology 7: 495–498.

Epp, H. T. 1983. Prehistoric settlement in two sand hill areas on the Saskatchewan Plains: archaeological design in action. Pages 183-198 *in* Tracking Ancient Hunters: Prehistoric Archaeology in Saskatchewan. *Edited by* H. T. Epp and I. Dyck. Saskatchewan Archaeological Society, Regina.

Hoffman, R. 1988. The contribution of raptorial birds to patterning in small mammal assemblages. Paleobiology 14(1): 81–90.

Kusmer, K. D. 1990. Taphonomy of owl pellet deposition. Journal of Paleontology 64(4): 629–637.

Lindroth, C. H. 1968. The ground-beetles (Carabidae, excl. Cicindelidae) of Canada and Alaska, Part 5. Opuscula Entomologica Supplementum 33: 649–944.

Nero, R. W. 1959. The Spadefoot Toad in Saskatchewan. The Blue Jay 17(1): 41–42.

Preston, W. B., and **D. R. M. Hatch.** 1986. The Plains Spadefoot, *Scaphiopus bombifrons*, in Manitoba. Canadian Field-Naturalist 100(1): 123–125.

Scott, J. S. 1971. Surficial geology of Rosetown Map-Area, Saskatchewan. Geological Survey of Canada Bulletin 190. 40 pages.

Terres, J. K. 1980. The Audobon Society Encyclopedia of North American Birds. Alfred A. Knopf, New York. 1109 pages.

Warner, R. E. 1976. The Genus *Otiorhynchus* in America North of Mexico (Coleoptera: Curculionidae). Proceedings of the Entomological Society of Washington 78: 240–262.

Received 17 June 1991
Accepted 6 April 1992

The Status of Selected Birds in East-central Alaska

ROBERT J. RITCHIE[1] and ROBERT E. AMBROSE[2]

[1]Alaska Biological Research, Inc., P.O. Box 81934, Fairbanks, Alaska 99708
[2]U.S. Fish and Wildlife Service, 1412 Airport Way, Fairbanks, Alaska 99701

Ritchie, Robert J., and Robert E. Ambrose. 1992. The status of selected birds in east-central Alaska. Canadian Field-Naturalist 106 (3): 316–320.

The status of 14 species of birds in east-central Alaska is discussed. Many records are unusual (first records), but information on distribution, abundance, and natural history of some species also is included.

Key Words: Birds, status, distribution, first records, east-central Alaska.

The avifauna of east-central Alaska, defined here as the drainages of the Porcupine, upper Yukon, and Tanana rivers (Figure 1), is well-known. Gabrielson and Lincoln (1959) summarized early records, and other researchers subsequently have clarified the status of a number of bird species in the region (Kessel 1960; Yocum 1963, 1964; White and Brooks 1964; Kessel and Springer 1966; Kessel 1967; White and Haugh 1969; Gibson 1972). Kessel and Gibson (1978) have provided the most recent and comprehensive update of Gabrielson and Lincoln's (1959) species accounts and have included many additional records for the region.

Since the mid-1970s, we have conducted breeding surveys of raptors along the rivers of east-central Alaska. During these investigations, we have recorded some unusual species as prey in Peregrine Falcon (*Falco peregrinus*) eyries (e.g., Brown Thrasher, *Toxostoma rufum*) and have made additional noteworthy observations (e.g., first nest records for the Townsend's Solitaire, *Myadestes townsendi*, in interior Alaska; Ritchie et al. 1982). The purpose of this paper is to summarize our records on 14 selected species of birds in east-central Alaska, to include notes on the natural history of some of these species, and to supplement the information on their status presented by Kessel and Gibson (1978).

Common Merganser (*Mergus merganser*)

Murie (*in* Gabrielson and Lincoln 1959: 244) "received a report that some [Common Mergansers] may occasionally winter on Clearwater River and Lake in the Tanana Valley." Murie also observed Common Mergansers and Mallards (*Anas platyrhynchos*) on the Clearwater River between 22 March and 7 April 1937 (unpublished notes, Rasmussen Library, Archives, University of Alaska, Fairbanks). Gabrielson and Lincoln (1959: 244) added that "there are, however, no unquestioned records for the interior at this season." The Common Merganser was identified as a regular winter resident in open-water areas west of Delta Junction during surveys for Bald Eagles (*Haliaeetus leucocephalus*) in January-February 1979-1981. For example, 47 birds were counted between Clearwater Lake (64°04'N, 145°35'W) and a point approximately 10 miles downriver from Delta Junction along the Tanana River on 14 February 1980.

Turkey Vulture (*Cathartes aura*)

Turkey Vultures are reported as casual as far north as east-central Alaska (American Ornithologists' Union 1983); this description was based on an observation of one Turkey Vulture observed near Delta Junction in May 1979 (American Birds. 1979. 33: 798). While counting Sandhill Cranes (*Grus canadensis*) on 3 May 1987, Richard Rohleder (Homer, Alaska, personal communication) observed a Turkey Vulture near Tok. This is only the second record from interior Alaska, although boreal records are not necessarily unusual (Palmer 1988a).

Merlin (*Falco columbarius*)

Although Merlins may be locally-common breeders in some mountainous regions of Alaska (e.g., Denali National Park; Dixon 1938, Murie 1963, Laing 1985), their breeding status in east-central Alaska best might have been described as uncommon. Only a few nests (University of Alaska Museum, unpublished nest records) and adults with fledged young (White and Haugh 1969) have been recorded north of the Alaska Range.

Our observations suggest that Merlins are common, at least along rivers, in east-central Alaska. We located 11 Merlin nests in the area between 1982 and 1986. Seven nests were on the Porcupine River, two were on the upper Tanana River, and two were on the upper Yukon River. Eight nests were in parasitic growths ("witch's broom" rust, *Chrysomyxa arctostaphyli*) on spruce trees (*Picea* spp.), one was on the ground beneath an uprooted tree, one was in a large stick nest on a cliff fronting the river, and one was in a Red-tailed Hawk (*Buteo jamaicensis*) nest in a Cottonwood (*Populus balsamifera*). Elsewhere, Merlins have been recorded

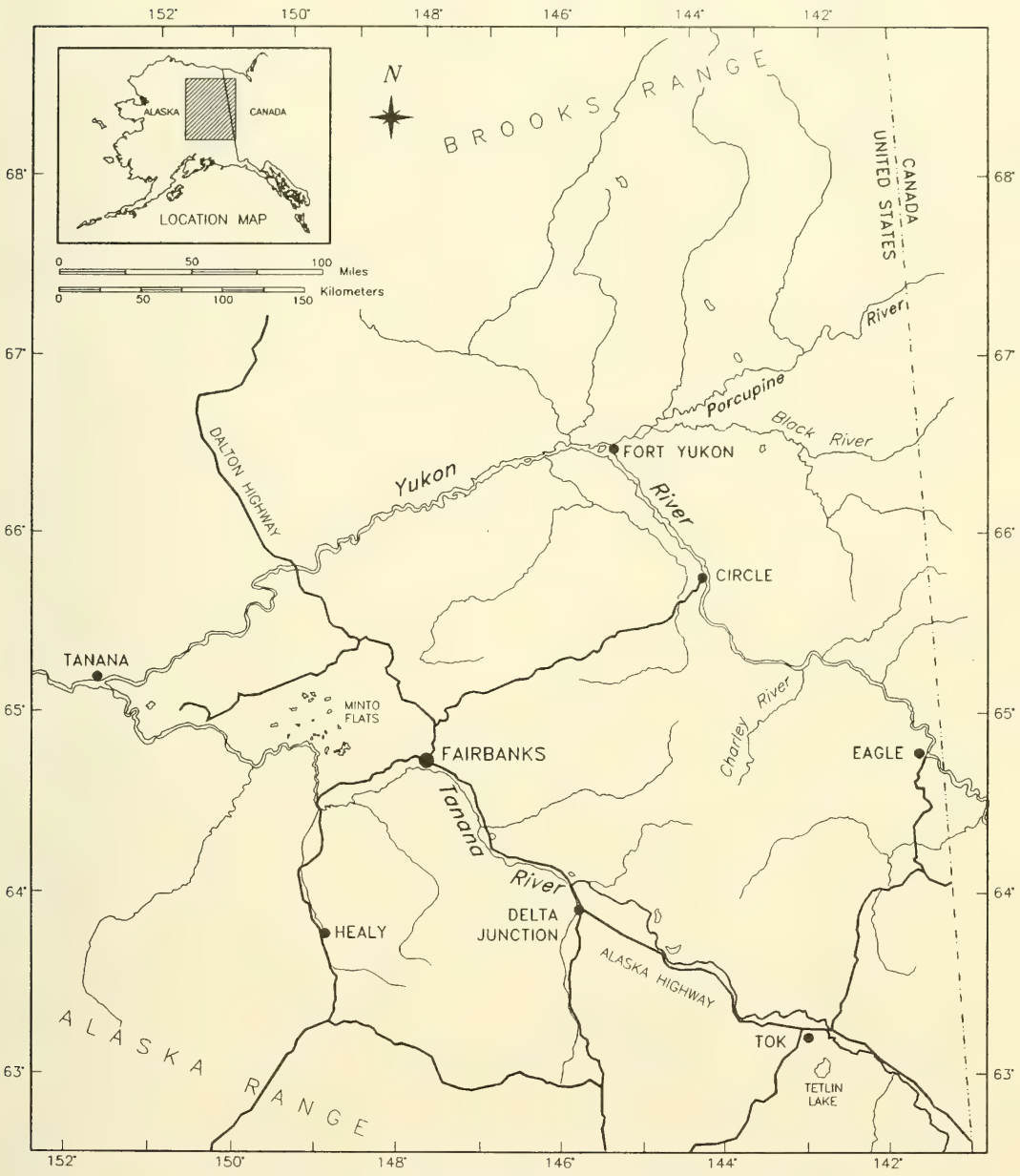


FIGURE 1. Map of east-central Alaska, showing areas referred to in the text.

nesting in abandoned nests of Black-billed Magpies, *Pica pica* (Dixon 1938; Laing 1985), nests of other corvids (Palmer 1988b), tree cavities (Bent 1937), and on the ground.

The prevalence of nests in parasitic growths is interesting but may simply reflect substrate limitations, because stick nests such as those constructed by magpies and used regularly by Merlins in Denali National Park (Laing 1985) are rare or absent in this region. Parasitic growths, on the other hand, are abundant in this region. Additionally, the value of these growths to Merlins may increase markedly if they are modified by a species such as the Red Squirrel (*Tamiasciurus hudsonicus*). Four of the nests that were located in parasitic growths may have been used previously by Red Squirrels. Bent

(1937) described a crow's nest in Labrador that had been used by squirrels before Merlins nested in it.

American Coot (*Fulica americana*)

Kessel and Gibson (1978) described the American Coot as a rare migrant and summer visitant in central Alaska. Most records were of single birds and were confined to the Tanana River basin between Tetlin Lake and Minto Flats. Trapp et al. (1981) found this species breeding in the Tanana River basin in 1980. Numerous sightings in 1980, including a group of 20 adults, probably were related to drought displacement from prairie wetlands, as has been described for some waterfowl (Hansen 1960). Associations between drought on the prairies and high duck populations in Alaska did occur in 1980 (James King, Juneau, Alaska, personal communication).

Our records of the regular occurrence of coots as prey remains in Peregrine Falcon nests offer further evidence of this species' occurrence in east-central Alaska. In 1980 and 1981, for instance, freshly-severed feet of two coots (one each year) were collected at Peregrine Falcon eyries along the upper Yukon River upriver from Circle. In 1981, remains of three coots also were collected at three Peregrine Falcon eyries along the Porcupine River, more than 400 km north of known breeding areas on the Tanana River. As was the case in 1980, 1981 was a year of high duck populations for Alaska (King and Conant, unpublished manuscript prepared for U. S. Fish and Wildlife Service, Juneau, Alaska), and additional records of coots may be related: concentrations were observed in fall 1980 in the upper Tanana River basin, including 50 birds on Yarger Lake (65°58'N, 141°40'W) on 18 September, and 1981 was the first year a coot was recorded in western Alaska (American Birds. 1981. 35: 970).

Upland Sandpiper (*Bartramia longicauda*)

Kessel and Gibson (1978) described the Upland Sandpiper as a rare spring and summer migrant and possible breeder in east-central Alaska. Although the Upland Sandpiper was observed rarely during our studies, its occurrence as fresh remains in Peregrine Falcon eyries in mid-July suggest that it may be more common in the region during summer than previously was thought. For example, 24 specimens of Upland Sandpiper (nearly 5% of all specimens collected) were identified in nests along the Porcupine River between 1979 and 1984. Upland Sandpipers also occurred, although less frequently, in Peregrine Falcon eyries on the upper Yukon and Tanana rivers during the same period; many of these individuals were freshly killed. The appearance of so many birds as prey in mid-summer collections at Peregrine Falcon nests, records of breeding in the Ogilvie Mountains of Canada (American Birds. 1979. 33: 789) and drainages on the southern slope of the Brooks Range in Alaska (Kessel and Schaller 1960; Campbell 1967), and suspected breeding in east-central Alaska's intermountain plateau (Kessel and Springer 1966) lead us to believe that Upland Sandpipers are regular summer visitants in upland areas adjacent to the Porcupine and Yukon rivers.

Ruddy Turnstone (*Arenaria interpres*)

The Ruddy Turnstone is considered a coastal bird outside of the breeding season, with only a few records in inland areas (Hayman et al. 1986). In Alaska, Gabrielson and Lincoln (1959) apparently considered the Ruddy Turnstone as coastal and listed only two inland records, at Anaktuvuk Pass. In 1987, we collected prey remains regularly from Peregrine Falcon eyries along the Yukon River upriver from Circle. Sometime between 6 July and 6 August that year, a Ruddy Turnstone was brought to one of these eyries; a single tarsus from this bird, complete with a faded, plastic color band, was found in this eyrie.

Pomarine Jaeger (*Stercorarius pomarinus*)

Gabrielson and Lincoln (1959) stated that the Pomarine Jaeger had the most restricted range in Alaska of any of the three jaeger species. Its breeding habitat is restricted to low-lying coastal areas (Maher 1974). There have been no previous sightings of this species in east-central Alaska. We recorded Pomarine Jaegers once along the upper Yukon River, a partially-eaten bird in a Peregrine Falcon eyrie on the Charley River in July 1983.

Caspian Tern (*Sterna caspia*)

Northern breeding colonies of the Caspian Tern occur in the Great Slave Lake region, in northern Alberta, and on the Pacific Coast as far north as Washington (American Ornithologists' Union 1983). Regular and recent records from southeastern (e.g., American Birds. 1981. 35: 853, 970) and south central Alaska (American Birds. 1983. 37: 1018) support suggestions that the Pacific Coast population is expanding and progressing northward (Campbell 1971; Gill and Mewaldt 1983).

We observed an adult Caspian Tern flying along the Yukon River upriver from Circle on 15 July 1984. The following day, U. S. National Park Service personnel observed a Caspian Tern near the Charley River, 12 miles east of the first sighting (Steve Ulvi, personal communication). These records are the first for the Caspian Tern in interior Alaska.

Eastern Kingbird (*Tyrannus tyrannus*)

Eastern Kingbirds have been described as casual summer and fall visitants to northern Alaska (Kessel and Gibson 1978) and the Yukon Territory (Godfrey 1966). In addition, there are single records for central Alaska at Delta Junction on 19 September 1976 (Kessel and Gibson 1978) and in the Susitna River drainage on 11 July 1980 (American Birds. 1980. 34: 921). Additional Alaska sightings are limited to southeastern Alaska (Kessel and Gibson 1978).

We recorded Eastern Kingbirds at two localities in

east-central Alaska. Two adult-plumaged birds observed on 21 July 1981 at Sam Creek (63°39'N, 144°04'W) were perched within a meter of each other in a tree on the edge of a flooded meadow. The second record came from the identification of a single Eastern Kingbird retrix found in a Peregrine Falcon eyrie on the Porcupine River in July 1984. The identification was verified by Roxy Laybourne (U. S. National Museum of Natural History, Washington, DC, personal communication). The sighting of a pair is interesting, because it suggests breeding. Sightings in the Yukon Territory provide further support for this suggestion: a pair on the Dempster Highway on 23 June 1979 (American Birds. 1979. 33: 879) and an adult feeding young at Snafu Lake on 26 July 1978 (American Birds. 1978. 32: 1186).

Mountain Bluebird (*Sialia currucoides*)

Mountain Bluebirds breed in east-central Alaska and the southern Yukon Territory (American Ornithologists' Union 1983). However, nest records in east-central Alaska are limited to a few locations in the Tanana drainage and south of the Arctic Circle: near Fairbanks, the Chisana River, the upper Tanana River (Kessel and Gibson 1978; William Lehnhausen, Fairbanks, Alaska, personal communication), and possibly at Eagle on the upper Yukon River (White and Haugh 1969).

During our investigations, we also recorded Mountain Bluebirds along the Yukon River between Eagle and Circle at three locations in 1984 and once in 1985, although they were not recorded there during research every year between 1973 and 1983. One 1984 record on the Yukon River (65°06'N, 141°28'W) was of a pair with fledged young. In 1985 and 1986, we identified bluebirds as prey in Peregrine Falcon eyries on the Yukon River upriver from Circle. In addition, we located a Mountain Bluebird nest containing three nearly-fledged young in a small cliff crevice on the Porcupine River (66°59'N, 142°41'W) on 1 July 1983.

Townsend's Solitaire (*Myadestes townsendi*)

Kessel and Gibson (1978) described the Townsend's Solitaire as a rare migrant and breeder in east-central Alaska. Our records, including the first nest records for Alaska (Ritchie et al. 1982), however, suggest that it is a regularly breeding species along the main rivers in east-central Alaska, especially on cliffs and dry, south-facing slopes that are vegetated with sagebrush (*Artemisia* spp.), Quaking Aspen (*Populus tremuloides*), and White Spruce (*Picea glauca*) forest. Along the Yukon River, it occurred regularly as prey in Peregrine Falcon eyries, being seen in four eyries in 1985 and in three eyries in 1986. It also was abundant in some areas (e.g., eight singing males recorded on cliffs along approximately 30 km of the upper Porcupine River, in June 1983).

Brown Thrasher (*Toxostoma rufum*)

The classification of the Brown Thrasher as accidental in Alaska was based on a single record of this bird from Point Barrow (Kessel and Gibson 1978) and on the fact that Brown Thrashers breed only as far north as southern Manitoba and Alberta (Godfrey 1966). Thus it was surprising to identify the distinctive rufous-colored retrices and tail coverts of this species in a Peregrine Falcon eyrie in east-central Alaska during each of two different years. The first specimen (U. A. M. No. 4283; identified by Richard Banks, U. S. National Museum of Natural History, personal communication; verified by Roxy Laybourne, personal communication) was found in a Peregrine Falcon eyrie on the Yukon River upriver from Circle in July 1983. The second record was collected from another Peregrine Falcon eyrie in July 1984; this nest was on the Black River, approximately 150 km north of the first collection site.

This coincidence probably was unique, because raptors have been known to select unusual, and consequently vulnerable, prey (Glue and Morgan 1977). However, a third interior specimen (U. A. M. No. 5683), a dead fall-plumaged adult brought in by a dog to its owner near the Robertson River on 27 May 1990, leaves us perplexed as to the actual status of this species in east-central Alaska.

Magnolia Warbler (*Dendroica magnolia*)

Magnolia Warblers are casual summer and fall visitants to southeastern Alaska and have been recorded as accidentals in both northern and western Alaska (Kessel and Gibson 1978). In 1986, the distinctive retrices of a Magnolia Warbler (U. A. M. No. 5364) were identified in the prey remains of a Peregrine Falcon eyrie on the Yukon River upriver from Circle.

Red-winged Blackbird (*Agelaius phoeniceus*)

Red-winged Blackbirds have been recorded breeding in the upper Tanana River valley as far west as George Lake; birds occasionally have reached Fairbanks (Kessel and Gibson 1978). We located a pair defending a nest on 1 June 1990 in the Goldstream Valley (64°54'N, 147°56'W), 16 km northwest of Fairbanks. The nest, which was built in cattails (*Typha latifolia*) on the edge of a pond, contained four eggs. Although the fate of this nest was not determined, a pair of Red-winged Blackbirds also was observed in this area in late June 1990 and 1991.

Acknowledgments

The following people assisted with our research projects: Ken Riddle, David Williamson, Doug Toelle, Campbell Bias, Lance Craighead, Michelle Ambrose, Bobbie Ritchie, James Hawkings, Robin Hunter, Don Ritchie, Rich Rohleder, Jim Curatolo,

Tom Cade, and Karen Bollinger. Dan Gibson and Brina Kessel assisted with unpublished records and allowed us to compare our specimens with study skins at the University of Alaska Museum, Fairbanks, Alaska. Funding for these studies was provided by the U. S. Fish and Wildlife Service, Alaska Biological Research, Northwest Alaska Gas Pipeline Co., and the U. S. Air Force. Robert Day, Brian Lawhead, Dan Gibson, W. B. Gillivray, and an anonymous reviewer reviewed drafts of this manuscript.

Literature Cited

American Ornithologists' Union. 1983. Check-list of North American birds. Sixth edition. American Ornithologists' Union, Washington, DC. 877 pages.

Bent, A. C. 1937. Life histories of North American birds of prey. United States National Museum Bulletin 170: 1–482.

Campbell, J. M. 1967. The Upland Plover in arctic Alaska. Murrelet 48: 28–33.

Campbell, R. W. 1971. Status of the Caspian Tern in British Columbia. Syesis 4: 185–189.

Dixon, J. S. 1938. Birds and mammals of Mount McKinley National Park, Alaska. Fauna of the National Parks of the United States, Fauna Series Number 3. 236 pages.

Gabrielson, I. N., and **F. C. Lincoln.** 1959. The birds of Alaska. Stackpole Co., Harrisburg, Pennsylvania. 922 pages.

Gibson, D. D. 1972. Sight records of two birds new to interior Alaska. Murrelet 53: 31–32.

Gill, R. E., Jr., and **L. R. Mewaldt.** 1983. Pacific coast Caspian Terns: dynamics of an expanding population. Auk 100: 369–381.

Glue, D., and **R. Morgan.** 1977. Recovery of bird rings in pellets and other prey traces of owls, hawks and falcons. Bird Study 24: 111–113.

Godfrey, W. E. 1966. The birds of Canada. National Museums of Canada, Ottawa. 595 pages.

Hansen, H. A. 1960. Changed status of several species of waterfowl in Alaska. Condor 62: 136–137.

Hayman, P., J. Marchant, and **T. Prater.** 1986. Shorebirds: an identification guide. Houghton Mifflin Co., Boston, Massachusetts. 412 pages.

Kessel, B. 1960. Additional distribution records of some birds in interior Alaska. Condor 62: 482–483.

Kessel, B. 1967. Late autumn and winter bird records from interior Alaska. Condor 69: 313–316.

Kessel, B., and **D. Gibson.** 1978. Status and distribution of Alaska birds. Studies in Avian Biology Number 1: 1–100.

Kessel, B., and **G. B. Schaller.** 1960. Birds of the Upper Sheenjek Valley, northeastern Alaska. Biological Papers of the University of Alaska Number 4: 1–58.

Kessel, B., and **H. K. Springer.** 1966. Recent data on status of some interior Alaska birds. Condor 68: 185–195.

Laing, K. 1985. Food habits and breeding biology of Merlins in Denali National Park, Alaska. Raptor Research 19: 42–51.

Maher, W. J. 1974. Ecology of Pomarine, Parasitic, and Long-tailed jaegers in northern Alaska. Pacific Coast Avifauna 37: 1–148.

Murie, A. 1963. Birds of Mount McKinley National Park, Alaska. Mt. McKinley Natural History Association, McKinley Park, Alaska. 86 pages.

Palmer, R. S. 1988a. Handbook of North American birds. Volume 4. Yale University Press, New Haven, Connecticut. 433 pages.

Palmer, R. S. 1988b. Handbook of North American birds. Volume 5. Yale University Press, New Haven, Connecticut. 465 pages.

Ritchie, R. J., J. A. Curatolo, and **F. L. Craighead.** 1982. First Townsend's Solitaire nest records for Alaska. Murrelet 63: 94–95.

Trapp, J. L., M. A. Robus, G. J. Tans, and **M. M. Tans.** 1981. First breeding record of the Sora and American Coot in Alaska — with comments on drought displacement. American Birds 35: 901–902.

White, C. M., and **W. S. Brooks.** 1964. Additional bird records for interior Alaska. Condor 66: 308.

White, C. M., and **J. R. Haugh.** 1969. Recent data on summer birds of the upper Yukon River, Alaska, and adjacent part of the Yukon Territory, Canada. Canadian Field-Naturalist 83: 257–271.

Yocum, C. F. 1963. Birds of the Tetlin Lake-Tok Junction-Northway area, Alaska. Murrelet 44: 1–6.

Yocum, C. F. 1964. Noteworthy records of birds from the Fort Yukon area and the Yukon Flats, Alaska. Murrelet 45: 30–36.

Received 21 June 1991
Accepted 28 April 1992

Habitat Change as a Factor in the Decline of the Western Canadian Loggerhead Shrike, *Lanius ludovicianus*, Population

EDMUND S. TELFER

Canadian Wildlife Service, Twin Atria Building, 4999 - 98 Edmonton, Alberta T6B 2X3

Telfer, E. S. 1992. Habitat change as a factor in the decline of the western Canadian Loggerhead Shrike, *Lanius ludovicianus*, population. Canadian Field-Naturalist 106(3): 321–326.

Field studies of habitat use by Loggerhead Shrikes (*Lanius ludovicianus*), a threatened species in Canada, on breeding range in Alberta and Saskatchewan and on winter range in Texas, confirmed their preference for short grass pastures. Regions of Alberta and Saskatchewan showing large declines in populations of breeding Loggerhead Shrikes in recent decades lost 39% of their unimproved pasture area through conversion to cropland between 1946 and 1986 and up to 79% of their pre-settlement pasture area. Regions where shrikes declined less lost only 12% of their unimproved pasture to cropland but had probably lost 65% of their pre-settlement pasture area. In probable shrike winter range in Texas, pasture area has also declined due to encroachment by cropland and brush invasion. In both Canada and Texas, Loggerhead Shrike management requires preservation and enhancement of remaining grasslands.

Des études sur le terrain ont confirmé que la Pie-grièche migratrice *Lanius ludovicianus*, une espèce menacée au Canada, préfère les pâturages à végétation basse comme habitat, que soit dans son aire de nidification en Alberta et en Saskatchewan ou dans son aire d'hivernage au Texas. Les régions de L'Alberta et de la Saskatchewan, où la population nidificante des Pies-grièches migratrices avait fortement diminué, ont perdu 39% des pâturages à l'etat de friche par la conversion en terres labourables entre 1946 et 1986, et jusqu'à 79% des aires de pâturage d'avant la colonisation. Les régions où la population des Pies-Grièches a la moine diminué avaient perdu seulement 12% des pâturages à l'etat de friche, mais probablement 65% des aires de pâturage d'avant la colonisation. Dans les aires d'hivernage probables de la Pie-Grièche au Texas, les aires de pâturage sont également moins nombreuses en raison de l'expansion des terres labourables et de l'envahissement par les broussailles. La gestion de la Pie-Grièche migratrice au Canada et au Texas nécessite la préservation et la mise en valeur des prairies qui restant.

Key Words: Loggerhead Shrike, *Lanius ludovicianus*, habitat, land use changes, Alberta, Saskatchewan, Texas.

Loggerhead Shrike populations have been declining in Canada and in the United States east of the Rocky Mountains since the 1960s (Morrison 1981; Cadman 1985; Tate 1986; Robbins et al. 1986). In Canada, concern over the decline resulted in the Loggerhead Shrike being designated a "threatened" species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), a body representing federal and provincial wildlife agencies. Past status and distribution of Loggerhead Shrikes in Alberta, Saskatchewan and Manitoba has been reviewed by Cadman (1985) and surveyed in 1987 (Telfer et al. 1989).

Although many causes for the decline of the Loggerhead Shrike have been suggested no one factor appears responsible. Habitat loss may be an important factor (Cadman 1985; Robbins et al. 1986). However, Brooks and Temple (1990a) pointed out that much apparently suitable nesting habitat is unoccupied. Habitat degradation on the winter range may also contribute to population declines. The present paper explores habitat changes that occurred in Alberta and Saskatchewan on the breeding range and in south Texas where the limited banding returns suggest many Canadian Loggerhead Shrikes winter (Burnside 1987).

Methods

Habitat Use

Loggerhead Shrikes are birds of the open country. They usually forage over short grass (Kridelbaugh 1982; Brooks and Temple 1990; Gawlik and Bildstein 1990) and hunt from elevated perches such as dead trees, tall shrubs and utility wires (Miller 1931; Bohall-Wood 1987; Luukkonen 1987). To evaluate shrike habitat selection during the nesting period we recorded land use in a 300 metre radius around shrike location sites in Alberta and Saskatchewan. Sixty observation sites were at nests; the other 102 sites rated in 1988 and 1989 were centered on birds on breeding range during the nesting season and that probably had nests nearby although the nests were not found. The area around each site was divided into four quadrants bounded by the cardinal directions. Each quadrant was then assigned to one of a series of land use categories ranging from native short grass prairie to housing developments.

The few recoveries of Loggerhead Shrikes banded during the breeding season in western Canada and adjacent states obtained from possible winter range have been included in the summary of long-distance movements of the species by Burnside (1987). Most recoveries were from Texas east of approximately 99

TABLE 1. Habitat of quadrants around 162 sites of Loggerhead Shrike observations in Alberta and Saskatchwan in 1988 and 1989.

	Habitat	Number of quadrants	Percent
1.	Pastures, some with shrub clumps	383	59.0
2.	Crops — grain, other crops, and fallow	235	36.0
3.	Farmyards, rights-of-way and townsites	20	5.0
4.	Brush and aspen groves	1	0.2
Total		648	

degrees west longitude and in an adjacent region of Oklahoma. Studies of winter range were therefore conducted in east Texas between 95 and 99 degrees west during February 1989. That part of Texas comprises the area between the heavily-forested region along the eastern border and the Balcones Escarpment on the west that separates east from west Texas. Resources did not permit surveys in other areas that may also be used by wintering Loggerhead Shrikes of the western Canadian breeding population.

The vegetation at 157 shrike location sites in east Texas was rated on structural characteristics along a continuum from well-grazed short grass pastures to closed oak and pine forests. Sites were grouped into three categories: (i) sites with more than 50% of the area within 300 metres in untreed short-grass pastures and mowed highway rights-of-way; (ii) areas with some scrub patches and trees and/or with tall (> 0.4 m) grass and forb stands or cropland; (iii) areas with more than 50% in scrub patches and forest stands.

Land Use Statistics

Canadian census data from the years between 1946 (before the decline in Loggerhead Shrike populations became apparent) and 1986 were examined. Changes in census subdivision boundaries in Manitoba made comparison of land use data uncertain so the analyses were confined to Alberta and Saskatchewan. In those provinces, boundaries of census subdivisions roughly coincided with regions established by Cadman (1985) as a framework for evaluating status and distribution of Loggerhead Shrikes and also used by Telfer et al. (1989) as a framework for reporting a survey of the shrike population in 1987. It was thus possible to examine land use change in regions that have suffered severe shrike population declines in comparison with regions of moderate decline.

American census statistics on land use proved difficult to relate to shrike habitat requirements. However, regional studies made in Texas have documented changes in vegetation and land use (Box 1967; Jurries 1979; Archer et al. 1988).

Results

Habitat Use

On the breeding range, shrikes showed an affinity for both untilled native grassland composed of endemic plant species and land seeded with introduced grasses and legumes. Fifty-nine percent of the quadrants around observation sites matched the pasture category compared to 36% for grainfields (Table 1). Frequency of occurrence of native grassland at observation sites was 76% compared to 56% for grainfields (Table 2). Although the proportion of those land use types along routes travelled in the course of making the observations was not documented, the Canadian census for 1986 showed that native pasture comprised 24% and grainfields 54% of the area in those census subdivisions that have maintained their shrike populations. Other land uses such as right-of-way, farmyards and townsites were less important to shrikes.

Observations of Loggerhead Shrikes on winter ranges in Texas showed a similiar pattern (Table 3). Sixty-one percent of observations were at sites in habitat Category I (> 50% short grass). Habitat Category II (tall grass, shrubs or cropland) dominated at 33% of sites. Sites dominated by shrub woodland or trees (habitat Category III) provided only 6% of the sightings. In most of those situations the high-

TABLE 2. Number of sites of Loggerhead Shrike observations at which at least one of the listed habitats occurred (Alberta and Saskatchewan, 1988 and 1989).

	Habitat	Number of sites[1]	Percent
1.	Pastures, some with shrub clumps	123	76.0
2.	Crops — grain, other crops, and fallow	90	56.0
3.	Farmyards, rights-of-way and townsites	22	14.0
4.	Brush and aspen groves	1	0.6

[1]162 sites in total. Where 2 habitat categories existed at a site it is included twice in this table.

TABLE 3. Habitat at 157 sites Loggerhead Shrike observations in central and south Texas, February 1989.

Habitat category	Number of observations	(Percent)
I[1]	95	61
II[2]	52	33
III[3]	10	6

[1]Open, short-grass habitat without trees.
[2]Cropland, brush stands with shortgrass patches, tall forb or grass.
[3]Largely brush and trees but with mowed highway right-of-way.

way right-of-way appeared to provide the foraging habitat. In all habitats utility wires were favoured perches for hunting shrikes.

Analysis of shrike habitat use at observation sites both on summer breeding range in Saskatchewan and in Alberta and on probable winter range in south Texas corroborated the many reports that shrikes prefer open habitats with short grass as the major feature in their home range during both summer and winter.

Land Use Statistics

The Canadian census category of "unimproved pasture" was considered to provide a useful index of shrike breeding habitat. Regions which experienced the most severe declines in shrike numbers (as shown by Telfer et al. 1989) had a 39% decline in unimproved pasture between 1946 and 1986 (Figure 1). This compared to a 12% decline in regions that retain substantial numbers of nesting shrikes (southwest and northwest Saskatchewan and southern Alberta as defined by Cadman 1985 and Telfer et al. 1989). Total area of unimproved pasture was also much less in 1986 in the areas with severe declines (3.3 million hectares compared to 8.7 million hectares in areas retaining substantial populations). In all regions the area of cultivated land (including land in grain and in summer fallow) increased steadily and substantially between 1946 and 1986.

On the winter range of Loggerhead Shrikes in Texas the 20 counties in which land use change was studied by Jurries (1979) exhibit similiar changes (Figure 2). Only 17% of the region remained in native grassland in 1979 (Figure 2) and provided the habitat most selected by Loggerhead Shrikes (Table 3). The improved pasture and other cultivated land also provided habitat used to some extent by shrikes. Nineteen percent of the total was covered by woody plants, described by Jurries (1979) as invaders. However, Jurries found that the total area occupied by woody invaders exceeded 60% of the original prairie area in two counties studied and 40% in three others.

Discussion

Loggerhead Shrike breeding range in Alberta and Saskatchewan is at the northern limit of the Northern Temperate Grassland Ecoregion as described by Shelford (1963). Shrikes migrate in winter to southern margins of that ecoregion. In both areas the veg-

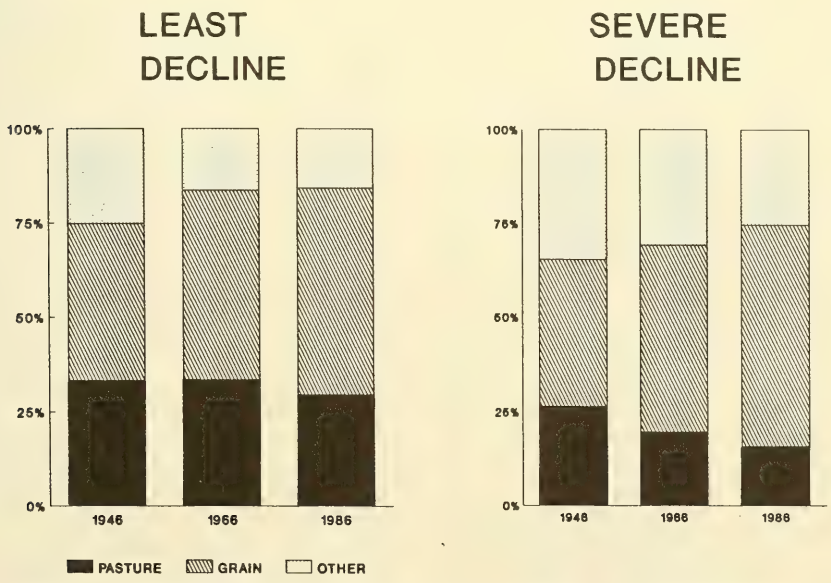


FIGURE 1. Changes of land use categories relevant to Loggerhead Shrike habitat of central and southern portions of Saskatchewan and Alberta between 1946 and 1986. "Other" lands included rights- of-way, farmsteads and urban areas.

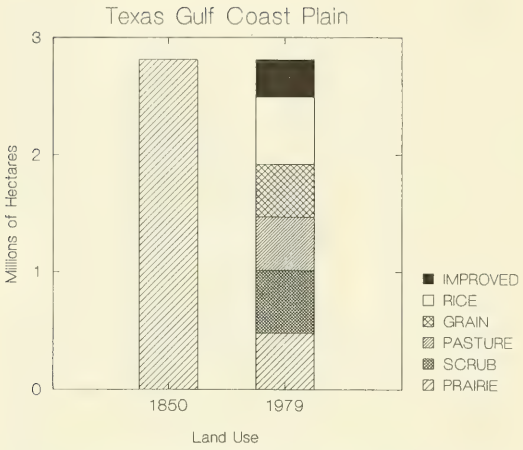


FIGURE 2. Land use changes in the Gulf Coast Prairie Region of Texas (After Jurries 1979).

etation was profoundly changed by European settlement and change continues down to the present. In southern Saskatchewan and Alberta early travellers reported extensive wildfire and a landscape with few trees or shrubs except along the river valleys (Spry 1968; Hind 1971). This landscape would have provided good foraging habitat for Loggerhead Shrikes. However, nesting habitat might have been scarce in severely burned districts. There, shrike use would have been restricted to sites having shrubs for nesting and perching. Suitable nesting habitat would have shifted over the landscape with the vagaries of the wildfire regime.

If the total area of potential nesting habitat under pre-settlement conditions is assumed to equal the 1986 total of unimproved pasture plus cultivated land then its extent would have been 24.7 million hectares in the regions of sustained Loggerhead Shrike numbers and 15.6 million hectares in the regions that have suffered large reductions in shrike numbers. Remaining unimproved pasture thus constitutes 35% of the original habitat in the areas of high densities but only 21% of the original total in present shrike low-density areas.

The northern edge of the Loggerhead Shrike breeding range in Alberta and Saskatchewan lies in the Aspen Parkland, a broad ecotone between the Grassland and Boreal Forest Ecoregions as described by Rowe (1972). Historically, forest growth in the Parkland was restrained by fire, and much of the area was prairie (Rowe 1972; Wright and Bailey 1982). However, shrubs and trees would have occurred and the area would have provided good shrike habitat especially where heavy grazing by bison (*Bison bison*) kept grasses short, providing the kind of hunting conditions selected by shrikes (Gawlik and Bildstein 1990).

With settlement by Europeans around 1900 there was a period of burning, land clearing and concentrated grazing and trampling by enclosed herds of livestock. These processes reduced much aspen forest to pasture and added to shrike habitat. However, the settlers also put a stop to the historic regime of frequent wildfires. Untilled areas filled in with dense stands of Aspen (*Populus tremuloides*). In one pasture area forest cover increased from 5% in 1940 to 68% in 1975 (Anderson and Bailey 1980). At the same time the increasing proportion of cultivated land reduced the area of forest overall. The resulting landscape pattern is one of cultivated fields interspersed with patches of aspen forest on wet, rough or broken land. This pattern provides limited habitat for Loggerhead Shrikes and may have been a factor in the decline in numbers of breeding shrikes, particularly in central Alberta and eastern Saskatchewan since the 1940s.

European settlement also led to fire suppression in the Mixed Grass Prairie region in southernmost Alberta and Saskatchewan. Settlers planted shelterbelts extensively around farmsteads. Native woody plant species also established themselves along railway and highway ditches and embankments and fence lines. With the wide distribution of shrubs through the Mixed Grass Prairie, many more nesting sites were provided that enabled Loggerhead Shrikes to use more of the excellent foraging habitat available there. Thus, one effect of settlement was to extend grassland/forest transition zone conditions further south and with it the good Loggerhead Shrike breeding habitat.

Early accounts of the pre-settlement landscape in parts of east Texas west and south of the forest zone speak of large treeless plains (Inglis 1964; Archer 1988). In the southern portion of east Texas brush and tree species occurred throughout in restricted patches along water courses and bluffs (Johnston 1963). Important species were Honey Mesquite (*Prosopis glandulosa*) and Huisache (*Acacia farnesiana*). Following the Anglo-American settlement of Texas in the nineteenth century, wildfires were gradually eliminated. Exclusion of fire combined with grazing and seed transport by livestock encouraged expansion of woody species into the prairie (Archer et al. 1988).

Brush encroachment has been a general problem throughout the ranching areas of Texas (Box 1967; Wright and Bailey 1982). Shrike winter habitat would have been increased initially by addition of perches in grassland as brush invaded but as stands closed habitat was lost.

In southern Texas grasslands expansion of cropland has been even more important than brush encroachment. Rice is a major crop. Ricefields are usually kept in fallow for two or three years between crops. However, dense stands of tall forbs grow on

the unplanted fields, rendering them marginal as shrike foraging habitat unless they are heavily grazed. Grain sorghum or milo is another important crop. Milo fields are tilled in autumn or early winter and in their unvegetated condition provide little food for shrikes in winter.

Increase in proportion of land devoted to row crops, increasing farm size and loss of hedgerows has also been suggested as a cause of decline in Loggerhead Shrike numbers in Arkansas, where they both breed and winter (Burnside and Shepherd 1985). Shrike declines and land use change were most pronounced in the Gulf Coast Plain ecoregion of Arkansas bordering east Texas. In Missouri, Kridelbaugh (1982) noted that Loggerhead Shrike numbers had declined in regions where pastures had been converted to row crops like soybeans or corn. He attributed shrike declines in the state to loss of grassland habitat.

Mechanisms by which adverse changes in habitat actually bring about decreases in bird populations may not produce immediate dramatic effects. They include: reduced quantity or quality of food; changes in habitat structure that increase foraging difficulty or expose nests to greater risk from weather or predators; increased competition with species that have similiar food or habitat requirements; higher mortality rates at all life stages due to predation, exposure, stress, disease or accident. In Saskatchewan and Alberta, the shift in the landscape from native prairie to grainfields and shelterbelts may have resulted in reduced Loggerhead Shrike productivity through increased nest predation, changes in available prey and increased difficulty of foraging in the taller and denser stands of grain compared to short, open stands of endemic prairie grasses. There is evidence that shrike productivity is lower in man-made compared to native grassland habitat (W. Harris, personal communication) while Luukkonen (1987) found productivity significantly higher at sites dominated by active pastures with closely-cropped grass in Virginia. However, in some years other habitats may be more productive probably due to impact of weather on insect prey (W. Harris, personal communication; Blumton 1989). Although, shrike reproductive success is generally high compared to other open-nesting passerines (Gawlik and Bildstein 1990), modelling by Brooks and Temple (1990b) has shown that, at the survival rates they estimated, shrikes would have to produce 5.5 young per pair to maintain the breeding population. That number substantially exceeds levels of productivity reported for most shrike studies. Similarly, Luukkonen (1987) modelled population change using productivity levels that he found in active pastures and in all other habitats. At the level found in pastures, the population would have declined by 6.9% per year while if productivity were limited to that found in the poorer habitats the decline would be 20.6% per year. Although data on mortality rates are inadequate these studies emphasize the importance of high-quality habitat to maintenance of Loggerhead Shrike numbers.

Loggerhead Shrikes that migrate to Texas and surrounding areas come into competition with year-round residents of the same species for the decreasing areas of optimum habitat (Brooks and Temple 1990b). They also may be in competition with wintering American Kestrels (*Falco sparverius*) (Bildstein and Grubb 1980). Loss of high-quality foraging habitat to the encroachment of brush and agriculture may contribute to further mortality. Deterioration in habitat quality must underlie the immediate causes of mortality in Loggerhead Shrikes and other species that are similarly situated. As habitat change continues apace, it will become increasingly important to focus research on the mechanisms by which habitat change translates into population change for Loggerhead Shrikes and other migratory bird species.

Management Implications

In Alberta and Saskatchewan the native prairie is prime Loggerhead Shrike habitat and its preservation is therefore important. Seeded pastures are poorer habitat but still better than crop or fallow, especially when they are older and if heavily grazed. If no suitable clumps of shrubs are available for nesting shrikes cannot use even good native prairie. The planting of at least one small patch of willows (*Salix* spp.), Thorny Buffaloberry (*Sheperdia argentea*) or of Caragana (*Caragana* spp.) per quarter section (64.75 ha) in fence corners or in moist areas would thus be a good management practice in such areas.

On the winter range in Texas human pressure on land is generally very great. Most land is in private hands and where soils are suitable for agriculture, few management practices for Loggerhead Shrikes appear possible. Where native prairie patches exist, their preservation should be encouraged. Brush encroachment is being resisted by ranchers using fire, herbicide and mechanical removal. Such range improvement helps Loggerhead Shrikes provided a few patches of shrubs remain for perches.

Acknowledgments

I wish to acknowledge the assistance of W. Harris of Prairie Environmental Services Incorporated; G. Blacklock of the Rob and Bessie Welder Wildlife Refuge; K. Risenhoover and K. Arnold of Texas A. and M. University; S. Labuda and R. Adamcik of the Attwater Prairie Chicken National Wildlife Refuge; E. Driver and A. Diamond of the Canadian Wildlife Service; and helpful reviews by A. Erskine and B. McGillivray.

Literature Cited

Anderson, H. G., and **A. W. Bailey.** 1980. Effects of annual burning on grassland in the aspen parkland of east central Alberta. Canadian Journal of Botany 58: 985–996.

Archer, S. 1989. Have southern Texas savannas been converted to woodlands in recent history? American Naturalist 134: 545–561.

Archer, S., C. Scifres, C. R. Bassham, and **R. Maggio.** 1988. Autogenic succession in subtropical savanna: conversion of grassland to thorn woodland. Ecological Monographs 58: 111–127.

Bildstein, K. L., and **T. C. Grubb, Jr.** 1980. Spatial distributions of American Kestrels and Loggerhead Shrikes wintering sympatrically in eastern Texas. Raptor Research 14: 90–91.

Blumton, A. K. 1989. Factors affecting Loggerhead Shrike mortality in Virgina. M.S. thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 85 pages.

Bohall-Wood, P. 1987. Abundance, habitat use, and perch use of Loggerhead Shrikes in north-central Florida. Wilson Bulletin 99: 82–86.

Box, T. W. 1967. Brush, fire, and west Texas rangeland. Proceedings of the Tall Timbers Fire Ecology Conference 6: 7–19.

Brooks, B. L., and **S. A. Temple.** 1990a. Habitat availability and suitability for Loggerhead Shrikes in the upper Midwest. American Midland Naturalist 123: 75–83.

Brooks, B. L., and **S. A. Temple.** 1990b. Dynamics of Loggerhead Shrike population in Minnesota. Wilson Bulletin 102: 441–450.

Burnside, F. L. 1987. Long-distance movements of Loggerhead Shrikes. Journal of Field Ornithology 58: 62–65.

Burnside, F. L., and **W. M. Shepherd.** 1985. Population trends of the Loggerhead Shrike (*Lanius ludovicianus*) in Arkansas. Arkansas Academy of Science Proceedings 39: 25–28.

Cadman, M. D. 1985. Status report on the Loggerhead Shrike (*Lanius ludovicianus*) in Canada. Unpublished Report to Committee on the Status of Endangered Species in Canada (COSEWIC). 97 pages.

Hind, H. Y. 1971. Narrative of the Canadian Red River exploring expedition of 1857 and of the Assiniboine and Saskatchewan exploring expedition of 1858 (Volumes I and II). Reprinted by G.M. Hurtig Ltd., Edmonton. 494 pages.

Gawlik, D. E., and **K. L. Bildstein.** 1990. Reproductive success and nesting habitat of Loggerhead Shrikes in north-central South Carolina. Wilson Bulletin 102: 37–48.

Inglis, J. M. 1964. A history of vegetation on the Rio Grande Plain. Texas Parks and Wildlife Department Bulletin Number 45. 114 pages.

Johnston, M. C. 1963. Past and present grasslands of southern Texas and northeastern Mexico. Ecology 44: 456–466.

Jurries, R. W. 1979. Attwaters prairie chicken. Texas Parks & Wildlife Department F.A. Series Number 18. 36 pages.

Kridelbaugh, A. L. 1982. An ecological study of Loggerhead Shrikes in central Missouri. M.S. thesis, University of Missouri, Columbia, Missouri. 42 pages.

Luukkonen, D. L. 1987. Status and breeding of the Loggerhead Shrike in Virginia. M.S. thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. 78 pages.

Miller, A. H. 1931. Systematic revision and natural history of the American shrikes (*Lanius*). University of California Publications in Zoology. Volume 38: 1–242.

Morrison, M. L. 1981. Population trends of the Loggerhead Shrike in the United States. American Birds 35: 754–757.

Robbins, C. S., D. Bystrak, and **P. H. Geissler.** 1986. The breeding bird survey: its first fifteen years, 1965-1979. U.S. Department of Interior, Fish and Wildlife Service Resource Publication 157. 196 pages.

Rowe, J. S. 1972. Forest regions of Canada, Canadian Forestry Service Publication Number 1300. 172 pages.

Shelford, V. E. 1963. The ecology of North America. University of Illinois Press, Urbana. 610 pages.

Spry, I. M. 1968. The papers of the Palliser expedition 1857-1860. The Champlain Society, Toronto. 694 pages.

Statistics Canada. 1946 et seq. Census of Canada, Agriculture.

Tate, J. Jr. 1986. The blue list for 1986. American Birds 40: 227–236.

Telfer, E. S., C. Adam, K. DeSmet, and **R. Wershler.** 1989. Status and distribution of the Loggerhead Shrike in western Canada. Canadian Wildlife Service Progress Note Number 184. 4 pages.

Wright, H.A., and **A. W. Bailey.** 1982. Fire ecology, United States and southern Canada. John Wiley & Sons, New York.

Received 8 July 1991
Accepted 2 March 1992

Diet of California Bighorn Sheep, *Ovis canadensis californiana*, in British Columbia: Assessing Optimal Foraging Habitat

Brian M. Wikeem[1] and Michael D. Pitt[2]

[1]British Columbia Ministry of Forests, Research Branch, Kamloops, British Columbia V2B 8A9
[2]Department of Plant Science, University of British Columbia, Vancouver, British Columbia V6T 1Z4

Wikeem, Brian M., and Michael D. Pitt. 1992. Diet of California Bighorn Sheep, *Ovis canadensis californiana*, in British Columbia: assessing optimal foraging habitat. Canadian Field-Naturalist 106(3): 327–335.

Monthly, seasonal, and annual food habits of California Bighorn Sheep (*Ovis canadensis californiana*) were related to forage quality, plant frequency, and foliar cover from May 1977 to April 1979, on a study site 10 km south of Penticton, British Columbia. During the two years, 14 grasses and sedges, 47 forbs and bryophytes, and 18 browse species averaged 66.6, 19.0, and 14.6% of the diet, respectively. Each forage group was selected by the sheep in proportions similar to average frequency on the site: grasses — 68.2%; forbs — 16.4%; browse — 15.2%. Bluebunch Wheatgrass (*Agropyron spicatum*) comprised the most common diet component (20.5%), followed by Prairie Junegrass (*Koeleria cristata*) (13.9%), Needle-and-thread (*Stipa comata*) (10.6%), Rough Fescue (*Festuca scabrella*) (8.0%), Cheatgrass (*Bromus tectorum*) (4.6%), and Arrowleaf Balsamroot (*Balsamorhiza sagittata*) (4.0%). Based on selection indices, most forage species were ingested randomly by the bighorn sheep. High (> 2.5) selection indices for Rough Fescue, Prairie Junegrass, Needle-and-thread, Kentucky Bluegrass (*Poa pratensis*), Thompson's Paintbrush (*Castilleja thompsonii*), Silky Lupine (*Lupinus sericeus*), Pasture Sage (*Artemisia frigida*), Snow Buckwheat (*Eriogonum niveum*), and Wyeth Buckwheat (*E. heracleoides*) were associated with a combination of phenological patterns, plant morphology, environmental site characteristics, and grazing preferences. Bluebunch Wheatgrass was generally selected in proportions less than available on the study site. Bighorn sheep diet correlated only poorly with crude protein, acid detergent fibre, calcium, and phosphorus. Diet frequency correlated most consistently with plant cover, suggesting that California Bighorn Sheep selected forages based primarily on plant availability.

Key Words: California Bighorn Sheep, *Ovis canadensis californiana*, British Columbia, diet, forage quality, selection.

Sugden (1961) characterized California Bighorn Sheep as opportunistic feeders that adapt their diets to forage availability. Indeed, 232 species have been recorded in California Bighorn Sheep diets throughout their range from California to British Columbia, including 42 grass and grasslike plants, 128 forbs, and 62 woody species (Wikeem 1984).

Despite an extensive literature (e.g., Jones 1950; Demarchi 1965; Blood 1967; Morrison 1972; Stelfox and Spalding 1974; Hickey 1978; Hansen 1982), relationships between seasonal forage selection and forage availability on California Bighorn Sheep ranges remain largely unclarified. No previous research has documented bighorn sheep diet in relation to quantified forage availability and quality. These simultaneous measurements are essential to understanding foraging ecology. In this paper we assess foraging patterns of California Bighorn Sheep by comparing monthly, seasonal, and annual diets with documented foliar cover and nutritional value of 13 managerially important or floristically dominant plant species. Using selection indices, we evaluate Sugden's (1961) hypothesis that bighorn sheep select forage species opportunistically. We also demonstrate that optimal California Bighorn Sheep habitat depends on a diversity of plant species, all of which contribute to diet quality during specific portions of the foraging year.

Study Area

The study area is 10 km south of Penticton, British Columbia, west of Skaha Lake (49°26'N, 119°37'W). Derived from glacial till, the soils are coarse-textured, and bedrock protrudes occasionally. Kelly and Spilsbury (1949) classified nearby soils as brown chernozems in the Skaha Gravelly Sandy Loam Series. Elevation of the generally steep-sloping topography ranges from 550 to 750 m with predominantly north and northeast exposures. The site is typical range for California Bighorn Sheep in the region, and formerly supported wild populations (Sugden 1961).

Annual precipitation at the Penticton airport, 6 km north of the study site, averages 296.1 mm, with bimodal peaks in January (31.5 mm) and June (35.6 mm). Highest mean daily maximum temperatures occur in July (28.6°C); coldest mean daily minimum temperatures prevail in January (-5.6°C). The frost free period averages 143 days (Environment Canada 1974).

The vegetation is transitional between the Big Sagebrush (*Artemisia tridentata*) and Ponderosa Pine (*Pinus ponderosa*) zones classified by McLean (1970). Dominant herbaceous plants include Bluebunch Wheatgrass (*Agropyron spicatum*), Cheatgrass (*Bromus tectorum*), Prairie Junegrass (*Koeleria cristata*), Needle-and-thread (*Stipa*

comata), Arrowleaf Balsamroot (*Balsamorhiza sagittata*), and Kentucky Bluegrass (*Poa pratensis*) in moist draws. Dominant woody species include Ponderosa Pine and Big Sagebrush, with Serviceberry (*Amelanchier alnifolia*), Douglas Maple (*Acer glabrum*), Common Chokecherry (*Prunus virginiana*) and Common Snowberry (*Symphoricarpos albus*) occurring in the draws. Plant taxonomy follows Hitchcock and Cronquist (1973).

Methods

In April 1977, 20 California Bighorn Sheep were released into a 42-ha enclosure. The sheep foraged exclusively on native vegetation, except in January 1978, when hay was provided because of thick snow cover. Mineral blocks and water were provided. Stocking density and herd structure were kept constant, by removing yearlings, to maintain 60–70% use of annual, herbaceous production. This use was prescribed to induce long-term floristic changes without restricting opportunity for diet selection by the bighorn sheep.

Bighorn sheep diet was determined by microhistological fecal analysis. Although this technique usually overestimates graminoids and underestimates forbs, fecal analysis generally yields accurate rankings of dietary components (McInnis et al. 1983) and provides the only practical method for determining diets of free-ranging herbivores (McInnis and Vavra 1987). Fecal samples were collected mid-monthly from 15 May 1977 to 15 April 1979. The sample years 1977 and 1978 hereafter refer to 15 May 1977-15 April 1978, and 15 May 1978-15 April 1979, respectively.

At each sampling period, the first 50 fresh pellet groups encountered were collected and frozen. Two pellets, randomly subsampled from each group, provided a monthly composite sample. Ten slides were prepared for each composite sample (Williams 1969), and 25 fields of view were sampled per slide at 100X magnification. Mean frequency was calculated for each plant species to determine diet composition. Monthly, seasonal, and annual diet differences were assessed with analysis of variance (ANOVA). Differences among means were evaluated with orthogonal contrasts or with the Student-Newman-Keul's procedure.

Frequency (%) and foliar cover (%) for all plant species were also determined mid-monthly by sampling 36 transects, evenly distributed over the study area. Frequency on all 30-m transects was determined with 100 Parker loops (1.9 cm in diameter) at 30-cm intervals (Parker 1951). Measurements coincided with fecal sampling from April to August in 1977 and 1978. Frequency and foliar cover for the months from September to March the following year were considered equivalent to values of the previous August. Comparisons of August and March data each year with ANOVA revealed no differences ($P > 0.05$) in species frequency or cover between these two months. Differences between years and among months in mean frequency and cover of species were determined with orthogonal contrasts or the Student-Newman-Keul's procedure following ANOVA.

Selectivity Index

Selection indices were calculated for forage groups and each plant species based on the following formula (Van Dyne and Heady 1965):

$$\text{Selection Index (SI)} = \frac{\text{Frequency (\%) of diet}}{\text{Frequency (\%) of forage}}$$

Seasonal selection indices were determined for summer (June-August), autumn (September-November), winter (December-February), and spring (March-May).

These selection indices represent point estimates without confidence intervals, which precludes statistical analysis for deviations from 1.0 (Hobbs 1982). We assumed, therefore, that an index > 2.5 indicates selection greater than expected by random removal, while an index < 0.7 indicates selection less than expected by random removal.

Relationships Among Diet Selection, Forage Quality, and Foliar Cover

Concentrations of nitrogen (N), acid detergent fibre (ADF), calcium (Ca) and phosphorus (P) were determined for Bluebunch Wheatgrass, Prairie Junegrass, Needle-and-thread, Sandberg's Bluegrass (*Poa sandbergii*), Cheatgrass, Arrowleaf Balsamroot, Silky Lupine (*Lupinus sericeus*), Wyeth Buckwheat (*Eriogonum heracleoides*), Snow Buckwheat (*E. niveum*), Big Sagebrush, Serviceberry, Common Snowberry and Pasture Sage (*Artemisia frigida*). Ten visually representative plants for each species were sampled mid-monthly from April to October 1977; March to November 1978; and March 1979, depending on available plant material.

Nitrogen was determined by the standard macro-Kjeldahl technique (Association of Official Analytical Chemists 1975) and converted to crude protein (CP) by multiplying by 6.25. Acid detergent fiber was determined by the van Soest method (van Soest 1963). Calcium and P were determined by the atomic absorption spectrometric method and the molybdate — vanadate method, respectively (Department of Animal Science, University of British Columbia 1979).

To determine relationships among bighorn diet, forage quality, and forage availability, stepwise multiple linear regressions of diet frequency on CP, Ca, P, ADF, the Ca/P ratio, and foliar cover were conducted for individual plant species and three forage groups (grasses, forbs, browse). These forage groups included the respective species of the 13 plants listed above. Monthly diet (% of all 13 species) and total diet (% of all 13 species at all monthly sample periods) were also regressed on these forage quality and

TABLE 1. SMonthly, seasonal, and annual diet of grasses, forbs, and browse (number of species) for captive Californiia Bighorn Sheep, Penticton, British Columbia, for the 1977 and 1978 sample years.

month and Season	Grasses		Forbs		Browse		Annual Total	
	1977	1978	1977	1978	1977	1978	1977	1978
June	9	9	12	9	11	8	32	26
July	9	7	11	15	9	11	29	33
August	9	9	10	15	7	10	26	34
Summer	10	10	17	21	13	14	40	45
September	11	11	9	14	9	9	29	34
October	10	10	11	10	12	5	33	25
November	10	8	7	10	12	10	29	28
Autumn	11	11	18	18	14	12	43	41
December	11	9	11	11	12	8	34	28
January	9	9	8	6	6	8	23	23
February	7	8	7	8	10	8	24	23
Winter	11	10	14	14	14	10	39	34
March	10	10	10	13	10	9	30	32
April	11	9	11	19	10	9	31	37
May	11	10	19	19	11	6	40	35
Spring	10	10	24	31	13	10	47	51

plant cover variables. Monthly diet regressions included the four months of most rapid plant growth (May-August), fall regrowth (October), and the period of lowest forage quality (March) before annual growth began in April.

Results

Diet Composition

Seventy-nine taxa occurred in the bighorn sheep diet, including 14 grasses and sedges, 47 forbs and bryophytes, and 18 woody species. In both 1977 and 1978, winter diet contained the fewest species, followed by spring peaks (Table 1). The number of grass and browse species in the diet varied little among seasons and months, whereas forb numbers averaged 27 in spring, compared to only 14 in winter (Table 1). Averaged over 1977 and 1978, the bighorn sheep diet included 66.6% grasses, 19.0% forbs, and 14.6% browse. Each forage group was selected by the sheep in proportions similar to average frequency on the site: grasses — 68.2%; forbs — 16.4%; browse — 15.2% (Table 2).

Diet frequency of grasses peaked ($P<0.05$) in autumn (73.7%) and winter (70.1%), and was lowest during summer (59.1%) and spring (63.6%) (Table 2). The bighorn sheep browsed least ($P<0.05$) during summer (8.9%), and most during winter (18.6%) and spring (17.6%). Forbs were grazed most in spring (18.8%) and summer (31.4%) but declined ($P< 0.05$) following senescence to 13.2 and 11.0% of the autumn and winter diet, respectively. Averaged over both years, Bluebunch Wheatgrass comprised the most common component of the diet (20.5%), followed by Prairie Junegrass (13.9%), Needle-and-thread (10.6%), Rough Fescue (*Festuca scabrella*) (8.0%), Cheatgrass (4.6%), and Arrowleaf Balsamroot (4.0%).

Diet frequency of grasses and forbs remained unchanged ($P> 0.05$) in 1978 compared to 1977 (Table 2). Although yearly variation ($P<0.05$) occurred for Prairie Junegrass, Rough Fescue, Needle-and-thread, Sandberg's Bluegrass and Thompson's Paintbrush (*Castilleja thompsonii*), absolute differences were negligible (Table 2).

Unlike grasses and forbs, diet frequency of browse differed ($P< 0.05$) between 1977 and 1978 (Table 2). Declines ($P< 0.05$) occurred for Snow Buckwheat, Common Chokecherry and "other" browse species, including Ponderosa Pine, Douglas-fir (*Pseudotsuga menziesii*), Sumac (*Rhus glabra*), and Squaw Currant (*Ribes cereum*) (Wikeem 1984). Common Rabbit-brush (*Chrysothamnus nauseosus*) was the only woody species that increased ($P<0.05$) in the diet between 1977 and 1978.

Diet Frequency in Relation to Forage Quality and Plant Cover

Bighorn diet correlated poorly with forage quality (Table 3). Crude protein, often presumed associated with grazing preference, did not enter any of the 10 regression equations for specific plant species. Acid detergent fibre negatively ($P< 0.05$) influenced diet frequency only of Arrowleaf Balsamroot; the Ca/P ratio negatively affected diet frequency only of Big Sagebrush. Even for monthly diet, forage groups, and total diet, forage quality parameters entered only 4 of 10 regression equations (Table 3).

Plant cover, however, consistently correlated with bighorn sheep diet frequency. Of 12 significant ($P< 0.05$) regressions, plant cover was included in 9.

TABLE 2. Seasonal diet frequency (%), site plant frequency (%), and selection indices (SI) for captive California Bighorn Sheep, Penticton, British Columbia, for the 1977 and 1978 sample years.

		Summer			Autumn			Winter			Spring			Annual Mean		
	Year	Diet	Site	SI	Diet	Site	SI	Diet	Site	SI	Diet	Site	SI	Diet	Site	SI
Grasses																
Bluebunch Wheatgrass	1977	15.7	33.4	0.5	18.1	33.8	0.5	26.7	33.8	0.8	18.0	30.2	0.6	19.6	26.1	0.8
	1978	18.0	32.5	0.6	17.3	36.3	0.5	30.8	36.3	0.9	19.7	30.8	0.6	21.4	34.0	0.6
Cheatgrass	1977	1.3	18.3	0.1	8.8	17.4	0.5	2.5	17.4	0.1	4.7	13.3	0.4	4.3	16.6	0.3
	1978	1.6	19.4	0.1	8.9	17.7	0.5	3.6	17.7	0.2	5.3	20.9	0.3	4.9	18.9	0.3
Rough Fescue	1977	13.9	0.5	27.7	8.1	0.3	27.1	1.9	0.3	6.3	4.4	0.2	22.0	7.1	0.3	23.7
	1978	6.9	0.4	17.3	9.3	0.5	18.4	9.2	0.5	18.4	10.1	0.4	25.3	8.9	0.4	22.3
Prairie Junegrass	1977	12.2	6.3	1.9	12.7	7.2	1.8	13.1	7.2	1.8	10.9	1.3	8.4	12.2	5.5	2.2
	1978	14.5	2.4	6.1	19.3	2.7	7.2	14.0	2.7	5.2	14.8	1.5	9.9	15.7	2.2	7.1
Kentucky Bluegrass	1977	1.9	1.3	1.4	2.9	1.0	2.9	2.9	1.0	2.9	2.3	1.0	2.3	2.5	1.1	2.3
	1978	2.9	1.1	2.4	8.5	1.4	6.1	3.2	1.4	2.3	4.0	1.7	2.4	4.7	1.4	3.4
Sandberg's Bluegrass	1977	0.5	2.8	0.2	2.1	3.2	0.6	0.0	3.2	0.0	5.5	10.2	0.5	2.0	4.9	0.4
	1978	0.3	2.8	0.1	1.7	2.6	0.7	0.5	2.6	0.2	2.8	7.4	0.4	1.3	3.9	0.3
Needle-and-thread	1977	9.2	6.5	1.4	10.7	5.2	2.1	15.2	5.2	2.9	13.1	0.6	20.4	12.1	5.1	2.4
	1978	8.3	3.9	2.1	10.5	5.4	2.0	11.5	5.4	2.1	7.1	3.1	2.2	9.2	4.5	2.1
Other grasses	1977	8.5	4.0	2.1	3.4	4.0	0.9	1.7	4.0	0.4	2.4	0.8	3.0	4.0	3.2	1.3
	1978	2.5	4.8	0.5	3.6	2.1	1.7	8.0	2.1	3.8	2.2	0.8	2.8	4.1	2.5	1.6
Total grass[1]	1977	63.2	73.1	0.9	67.6	72.1	0.9	64.0	72.1	0.9	61.3	57.6	1.1	64.0	68.7	0.9
	1978	55.0	67.3	0.8	79.7	68.7	1.2	76.2	68.7	1.7	66.0	66.6	1.0	69.2	67.8	1.0
Forbs																
Yarrow	1977	0.5	0.6	0.8	2.4	0.3	8.0	0.1	0.3	0.3	0.9	1.0	0.9	1.0	0.6	1.7
	1978	0.8	1.2	0.7	1.3	1.1	1.2	0.3	1.1	0.3	0.7	1.2	0.6	0.8	1.2	0.7
Arrowleaf Balsamroot	1977	7.3	3.1	2.4	0.0	3.1	0.0	0.7	3.1	0.2	4.8	2.7	1.8	3.2	3.0	1.1
	1978	13.9	5.6	2.5	0.0	3.4	0.0	2.3	3.4	0.7	2.9	2.4	1.2	4.8	3.7	1.3
Thompson's Paintbrush	1977	2.7	0.1	27.0	1.1	T[2]	NC[3]	0.0	T	NC	0.3	0.2	1.5	1.0	0.1	10.0
	1978	0.8	0.2	4.0	0.0	0.1	0.0	0.0	0.1	0.0	0.8	0.2	4.0	0.4	0.2	2.0
Silky Lupine	1977	2.5	0.2	12.5	0.3	0.1	3.0	0.5	0.1	5.0	2.9	0.5	5.8	1.6	0.2	8.0
	1978	4.8	0.8	6.0	0.1	0.3	0.3	0.1	0.3	0.3	1.9	0.3	6.3	1.7	0.4	4.3
Other forbs	1977	13.5	7.7	1.8	11.6	8.3	1.4	14.0	7.6	1.8	10.3	22.5	0.5	12.4	11.5	1.1
	1978	15.9	10.8	1.5	9.7	10.4	0.9	4.0	9.0	0.4	12.1	15.0	0.8	10.4	11.3	0.9
Total forbs	1977	26.5	11.7	2.3	15.4	11.8	1.3	15.3	11.8	1.3	19.2	26.9	0.7	19.8	15.6	1.2
	1978	36.2	19.0	1.9	11.1	15.3	0.7	6.7	15.3	0.4	18.4	19.1	1.0	18.1	17.2	1.1
Browse																
Serviceberry	1977	2.4	T	NC	1.7	T	NC	2.0	T	NC	4.3	T	NC	2.6	T	NC
	1978	1.6	T	NC	1.1	T	NC	3.7	T	NC	6.4	T	NC	0.4	T	NC
Pasture Sage	1977	0.1	0.1	1.0	0.6	T	NC	0.4	T	NC	0.3	T	NC	0.4	T	NC
	1978	0.4	0.1	4.0	0.6	0.1	6.0	0.3	0.1	3.0	0.1	0.1	1.0	0.4	0.1	4.0
Big Sagebrush	1977	0.3	10.3	0.0	0.4	10.7	0.0	1.7	10.7	0.2	2.1	11.4	0.2	1.1	10.8	0.1
	1978	0.1	10.4	0.0	1.1	12.1	0.1	2.1	12.1	0.2	0.2	11.9	0.0	0.9	11.6	0.1
Wyeth Buckwheat	1977	1.1	1.2	0.9	4.3	1.2	3.3	7.1	1.2	5.9	2.9	1.1	2.6	3.4	1.2	2.8
	1978	0.9	0.9	1.0	2.9	0.9	3.2	5.7	0.9	6.3	2.8	0.6	4.7	3.1	0.8	3.9
Snow Buckwheat	1977	0.7	2.3	0.3	2.7	2.6	1.0	4.9	2.6	1.9	3.9	1.4	2.8	3.1	2.2	1.4
	1978	0.1	1.1	0.1	0.4	1.4	0.3	3.1	1.4	0.7	3.1	0.6	5.2	1.7	1.2	1.4
Other browse	1977	6.0	0.6	10.0	7.2	1.0	7.2	4.5	1.0	4.5	5.6	1.0	5.6	5.8	0.9	6.4
	1978	3.2	0.8	4.0	3.1	1.0	3.1	2.1	1.0	2.1	2.7	0.6	4.5	2.8	0.9	3.1
Total browse	1977	10.3	14.9	0.7	17.1	16.0	1.1	20.1	16.0	1.3	19.5	15.5	1.3	16.8	15.6	1.1
	1978	7.5	13.6	0.6	9.2	15.9	0.6	17.2	15.9	1.1	15.6	14.3	1.1	12.4	14.9	0.8

[1]Totals for a forage group may not equal the sum of individual species due to rounding or trace values.
[2]Trace <0.1.
[3]Selection Index not calculated due to division by trace values.

Moreover, in 8 of these 12 regressions, only plant cover correlated with diet frequency, explaining between 20 and 62% of all variation in bighorn sheep diet.

Discussion

Selection indices, which compare diet frequency and plant availability, are typically used to describe use of forage species different than expected from

TABLE 3. Stepwise multiple linear and polynomial regressions relating captive California Bighorn Sheep diet to forage quality and plant cover, Penticton, British Columbia, for the 1977 and 1978 sample years.[1]

Diet	n	$Y = b_0 +$ CP (%)	+ ADF (%)	+ Ca (%)	+ P (ppm)	+ Ca/P (ppm)	+ Cover (%)	R^2
May	25	2.87					0.44	0.29[2]
June	27	–0.15		0.46			0.46	0.35
July	25	2.63					0.48	0.20
August	25	3.49					0.63	0.28
October	11	ns						
March	16	3.96					0.65	0.36
Bluebunch Wheatgrass	14	ns						
Cheatgrass	14	ns						
Prairie Junegrass	11	ns						
Needle-and-thread	13	ns						
Arrowleaf Balsamroot	8	45.13	–0.79					0.63
Silky Lupine	8	0.83					6.86	0.62
Pasture Sage	12	ns						
Big Sagebrush	12	–2.19				–2.19		0.40
Snow Buckwheat	12	ns						
Wyeth Buckwheat	12	ns						
Grass species	63	4.88				1.48	0.22	0.24
Forb species	27	0.54					3.31	0.62
Browse species	57	0.15				0.27		0.19
All species	147	–11.96	0.32	0.29	1.81		0.55	0.35

[1]b_0 is the intercept, n is the sample size, and R^2 is the coefficient of determination. Sample size corresponds to the number of months or species included in each regression. Because of insufficient plant material during some monthly sample periods, no regression equations were developed for Sandberg's Bluegrass, Serviceberry, and Common Snowberry.
[2]Only those regression equations significant at $P<0.05$ are included.

random grazing. An index > 1.0 presumably indicates selection for, whereas an index < 1.0 implies selection against a plant species. An index equal to 1.0 suggests random grazing, with no selection for or against the plant species.

Selection indices different from 1.0, however, should not be confused as synonymous with animal avoidance or preference. Heady (1975) indicated that selection comprises three broad categories: plant palatability, animal preference, and environmental factors. Plant palatability is influenced by chemical composition, proportion of plant parts, growth stage, external plant form, and availability of alternative forages. Animal preference is influenced by the senses, learned and evolved behavior, age, physical state, and rumino-reticular volume (Hanley 1982). Environmental factors include weather, topography, soil fertility, slope, aspect, and management practices. Thus, selection is determined by a variety of factors, only one of which is animal preference.

Unfortunately, biologists and resource managers occasionally ignore this complexity by interpreting selection indices as something more than simply a diet/availability ratio. High or low selection indices are occasionally mistaken to indicate animal preference or avoidance of plant species or habitats. For example, based on selection indices < 1.0, Fairbanks et al. (1987) concluded that grasslands were "avoided" by Rocky Mountain Bighorn Sheep (*Ovis canadensis canadensis*) during all seasons, even though sheep used grassland (41-63% of all sheep observations) more than any other habitat type. Alternatively, even without conscious choice, coincidentally ingested rare species will produce high selection indices.

In reality, selection indices incorporate much more than forage or habitat preference. Forage selection integrates conscious choice with all other plant, animal and environmental factors affecting ingestion by grazing animals, many of which are inextricably confounded. Diet/availability ratios do not directly quantify forage preference, but rather indicate grazing patterns different from those expected from random use. Non-random forage selection may result from grazing behavior, animal preference, forage quality, or a combination of these factors. Our discussion of selection indices attempts to distinguish among the complex of factors affecting bighorn sheep diet.

Selection Indices

Grasses, forbs, and browse, were generally selected in proportions similar to frequency (SI approximately = 1.0) on the study site (Table 2). Moreover, most of the 79 forage species on the study site displayed SI's between 0.7 and 2.5 (Wikeem 1984).

Nonetheless, the bighorn sheep did select some plants differently than expected by random grazing.

Bighorn sheep highly selected (SI = 23) Rough Fescue, which provided < 1% of study site plant frequency during all seasons and years (Table 2). Use of Rough Fescue may be attributed not only to its presumed palatability, but also to its distribution and availability on the study site. Rough Fescue occurred mostly within Ponderosa Pine stands, used by the sheep for bedding year-round and for shade in summer. Heavy snowfalls in winter 1977, however, limited bighorn sheep access to these higher elevation bedding sites. Selection indices for Rough Fescue in winter 1977, therefore, were lower than in winter 1978 (Table 2) because of reduced availability. Thus, high SI values for Rough Fescue are likely associated with its proximity to preferred bedding and shaded habitat in addition to grazing preference.

Diet frequency of Prairie Junegrass exceeded 10.0% during all eight seasonal grazing periods, but during summer, autumn, and winter of 1977, the bighorn sheep displayed no selection for this species (Table 2). Thereafter, however, SI's ranged from 5.2 to 9.9, with the highest SI for Prairie Junegrass occurring in spring during both 1978 and 1979 (Table 2). Prairie Junegrass is a small bunchgrass, with a high proportion of foliage compared to culms. The bighorn sheep may have selected this species based on suitable morphological features, rather than purposeful selection for nutritive characteristics. A similar explanation exists for Needle-and-thread, which averaged 10.6% diet frequency over the study period. Only during spring 1977, however, did the SI indicate selection of Needle-and-thread (Table 2). At this time, the basal leaves of this species were readily available and grazed by the bighorn sheep.

In contrast to these two grass species, Sandberg's Bluegrass exhibited low SI's (Table 2). This small bunchgrass produces scanty foliage that matures early in the growing season when numerous other grasses and forbs are also available. Low selection indices, therefore, may result from phenological pattern, with reduced relative availability, rather than low nutritive quality.

Although no other plant species contributed as much to bighorn sheep diet as Bluebunch Wheatgrass, only during winter did the SI for Bluebunch Wheatgrass approach 1.0 (Table 2). Diet frequency of Bluebunch Wheatgrass peaked in January (29.8%) and February (33.2%), when snow cover restricted availability of other forages. Bluebunch Wheatgrass culms generally protruded above the snow, thereby remaining more visible and available to the sheep. Beginning in spring, forbs and new growth of browse once again became available to the bighorn sheep. Bluebunch Wheatgrass, therefore, declined ($P < 0.05$) to its lowest diet level in June (15.2%) when forbs were most available.

These results suggest opportunistic use of Bluebunch Wheatgrass based on relative availability, with low SI's resulting primarily because of high site frequency. For example, Bluebunch Wheatgrass averaged 30% frequency over the 2-year period. To produce a selection index of 2.5, bighorn sheep diet would have to contain 75% Bluebunch Wheatgrass, a figure highly unlikely for an animal with a broad food niche. An index < 0.7 for such an abundant species does not necessarily indicate conscious aversion, as Bluebunch Wheatgrass may be consumed as readily as other plants encountered.

Cheatgrass contributed most to bighorn diet in October (9.0%) and November (8.6%) after autumn germination, and in March (7.0%) when it provided green forage before other plant species began growth. Similar spring foraging patterns on Cheatgrass were reported for mountain sheep in Idaho (Smith 1954) and British Columbia (Blood 1967). Nevertheless, SI values for Cheatgrass never exceeded 0.5. During summer, the bighorn sheep selected against Cheatgrass (Table 2), likely because of unpalatable awns and pubescent culms.

Averaged over all seasons, selection indices for forbs indicated random use in 1977 and 1978 (Table 2). Within and among seasons, however, SI's varied for specific species and life-forms. Selection indices for all 12 annual forbs generally fell below 0.7, as their maximum diet frequency equalled only 1.6% (Wikeem 1984). Low SI's for annual forbs likely occurred because they produce very little forage, with short periods of availability compared to other plant species.

Higher selection indices occurred for perennial forbs. Averaged over both years, Arrowleaf Balsamroot and Silky Lupine comprised 10.6% (SI = 2.4) and 3.6% (SI = 9.2) of the summer diet. Selection for these species likely reflected grazing preference in addition to opportunistic foraging, particularly during May and June of 1977 and 1978, when both species contributed significantly to diet. Arrowleaf Balsamroot was not selected in autumn after senescence (SI = 0.0), but SI's for Silky Lupine remained above 2.5 during autumn, winter and spring in 1977 (Table 2).

Thompson's Paintbrush averaged only 1.8% diet frequency over the study period. Nonetheless, this grazing use produced a high selection index (27.0) during summer 1977 (Table 2), likely because of very low availability. Other perennial forbs with low availability producing SI's > 2.5 during summer included Holboell's Rockcress (*Arabis holboellii*), Diffuse Knapweed (*Centaurea diffusa*), Thread-leaf Fleabane (*Erigeron filifolius*), Brown-eyed Susan (*Gaillardia aristata*), Old Man's Whiskers (*Geum trifolium*), Columbia Puccoon, and Long-leaf Phlox (*Phlox longifolia*). Such non-random selection probably reflects opportunistic foraging rather than purposeful grazing preference.

Most browse species also exhibited SI's > 2.5, even though diet frequency often remained low (Table 2). Pasture Sage averaged only 0.4% of the diet, with

highest frequency occurring in autumn. Selection indices ($\bar{x}$ = 4.0), however, remained high for Pasture Sage during all seasons except spring. Previous studies from British Columbia also recorded Pasture Sage in California Bighorn Sheep diets, especially during winter (Demarchi 1965; Morrison 1972).

Wyeth Buckwheat and Snow Buckwheat were also grazed consistently in both years. Selection indices for Wyeth Buckwheat remained high during all seasons except summer, with highest selection occurring in winter (SI = 6.1), when diet frequency averaged 6.4% (Table 2). Peak selection (SI = 4.0) of Snow Buckwheat occurred in spring (Table 2), particularly in March, when diet frequency equalled 6.6%. These selection indices likely indicated high animal preference, as the bighorn sheep browsed both species intensively, with use equalling 83 and 93% for Snow Buckwheat in 1977 and 1978, respectively (Wikeem 1984). Moreover, frequency of Wyeth Buckwheat and Snow Buckwheat both declined ($P \leq 0.05$) in areas grazed by the sheep, compared to areas protected from grazing (Wikeem 1984).

Serviceberry also contributed significantly to the diet in March (8.2%), as the sheep stripped virtually all available leaves within a 2-m height zone (Wikeem and Pitt 1987). Selection indices are unavailable, however, as no Serviceberry occurred on the transects. Other browse used in spring and summer included Douglas Maple, Mockorange (*Philadelphus lewisii*), Common Chokecherry, Nootka Rose (*Rosa nutkana*) and Common Snowberry. Common Rabbit-brush, Ponderosa Pine, and Douglas-fir, were grazed most during autumn and winter (Wikeem 1984).

Big Sagebrush diet frequency averaged only 1.0%, and SI's ranged from 0.0 to 0.2, even though it was the most common shrub on the site (Table 2). Low levels of Big Sagebrush use by mountain sheep were also found in Nevada (Hansen 1982) and Wyoming (Oldemeyer et al. 1971). Stewart (1975), however, reported that Rocky Mountain Bighorn Sheep diets in Montana contained 43% Big Sagebrush.

Such variable use of Big Sagebrush among bighorn sheep populations may be associated with differential proportions of essential oils and palatability among Big Sagebrush ecotypes (Plummer 1972). Selection against Big Sagebrush on our study site likely did not occur because of low nutritive value. Crude protein of Big Sagebrush was often equivalent to, or higher than Pasture Sage, Snow Buckwheat, and Wyeth Buckwheat, browse species for which the SI exceeded 2.5 during one or more seasons (Wikeem 1984).

The regressions of diet frequency on forage quality further support Sugden's (1961) hypothesis that bighorn sheep graze opportunistically, rather than seeking specific plant species or forage nutrients. Six of 10 regressions for plant species produced no significant relationships with any forage quality parameters. During May, July, August, and March, only total plant cover correlated ($P < 0.05$) with diet frequency.

Neither forage quality, nor total plant cover, however, produced significant ($P > 0.05$) stepwise regressions for diet frequency in October (Table 3), despite improved nutritional quality of autumn regrowth (Wikeem 1984). Only a comparatively few plant species produced significant fall regrowth, however, which collectively accounted for only 82 kg/ha (11.5% of total annual herbage production) in 1978 (Wikeem 1984). This regrowth was likely too heterogeneously distributed for sheep to graze specifically for enhanced forage quality.

Strasia et al. (1970) similarly reported significant linear regressions between plant cover and diet selection of domestic sheep on alpine ranges, particularly for forbs. Ellis et al. (1976) also noted that consumption of a plant species "generally increases with availability or density of the food item up to some 'saturation level' beyond which further increases in food availability do not affect consumption."

Bighorn sheep, which move constantly while grazing, are more likely to encounter and ingest both widely-distributed and frequently-occurring plant species. This grazing pattern can produce selection indices either > or < 1.0 depending on spatial distributions of plant species. In both cases, selection for and against may result from opportunistic grazing rather than conscious choice. This was evident in the variable use of infrequently occurring species between 1977 and 1978. Liddon's Sedge (*Carex petasata*), Slender Hawksbeard (*Crepis atrabarba*), Bastard Toad-flax (*Comandra umbellata*), Yellow Bell (*Fritillaria pudica*), Indian-wheat (*Plantago patagonica*), Shrubby Penstemon (*Penstemon fruticosus*) and Sumac were grazed only in 1977, while Timber Milkvetch, Pursh's Milkvetch (*Astragalus purshii*), Holboell's Rockcress, Little Larkspur (*Delphinium bicolor*), Sticky Shooting Star, Roundleaf Alumroot (*Heuchera cylindrica*), Large-fruit Desert Parsley (*Lomatium macrocarpum*), Brittle Prickly-pear Cactus (*Opuntia fragilis*), Silverleaf Phacelia (*Phacelia hastata*), Night-flowering Silene (*Silene noctiflora*), Tumblemustard (*Sisymbrium altissimum*), and Meadow Death-camas (*Zigadenus venenosus*) were grazed only during 1978.

The relationship between diet selection and plant cover may be associated with succulence and relative plant maturity. For example, Kentucky Bluegrass, which occurred primarily in draws and other mesic sites, remained green beyond the onset of summer drought. During autumn, SI values for Kentucky Bluegrass exceeded 2.5 in 1977 and 1978 (Table 2), reflecting maximum diet frequency in October (5.2%) and November (7.8%). Similarly, we observed that bighorn sheep grazed selectively for (1) new growth over old growth in grasses, (2) leaves over stems on browse (e.g., Serviceberry, Common Chokecherry, Douglas Maple), and (3)

flower heads of shrubs and forbs, especially Yarrow (*Achillea millefolium*), Twin Arnica (*Arnica sororia*), Arrowleaf Balsamroot, Brown-eyed Susan, Goatsbeard (*Tragopogon dubius*), and Common Rabbit-brush. Likewise, Prairie Junegrass, Needle-and-thread, and Rough Fescue all had higher selection indices than Bluebunch Wheatgrass, which retains higher proportions of coarse leaves from previous growing seasons.

Conclusions

Buechner (1960) and Geist (1971) indicated that habitat quality is fundamental for maintaining productive mountain sheep populations. Our results suggest that quality of California Bighorn Sheep habitat depends more on forage diversity and nutritional balance (Westoby 1974) than on management programs that maximize specific nutrients or plant species.

California Bighorn Sheep readily adjust their diet to changing forage availability. Moreover, our results indicate that a number of plant, animal, and environmental factors combine to determine forage acceptability to California Bighorn Sheep, which likely select each plant species for a different set of factors. Most plant species contributed to the bighorn sheep diet during at least one season of the year. The similarity in total numbers of plant species in the diet between 1977 and 1978 further reflects a preference of California Bighorn Sheep for habitats with wide species diversity. Although bighorn sheep grazing produced high selection indices for some plant species, grazing preference based on forage nutrition was not likely a sole causative factor. Bighorn sheep, as most ruminants, evolved as grazing generalists, capable of digesting a wide variety of plant species. Such an adaptation optimizes nutritive value of the entire diet rather than maximizing acquisition of specific nutrients concentrated in a few plant species.

Grasses, forbs, and browse all contribute nutritionally to bighorn sheep diet during specific portions of the year. Grasses generally provide spring growth, autumn regrowth, and a cured forage relatively high in energy (Cook 1972). Grasses, therefore, comprised a substantial portion of bighorn sheep diet during all seasons, particularly autumn and winter (Table 2) when average energy levels may be higher than in forbs and browse (Cook 1972).

Browse provides year-round forage for bighorn sheep, even in plant communities dominated by herbaceous plants. Deciduous browse species supply leafy forage throughout the growing season, while woody material is permanently available. Non-deciduous browse species provide leafy and woody material throughout the year. The proportion of CP and P in this woody material often exceeds that of grasses and forbs following plant maturity in autumn (Cook 1972).

Forbs, especially annual species, generally deteriorate quickly following plant maturity (Oelberg 1956; Cook 1972), with correspondingly low forage value and palatability in autumn and winter. Greatest diet frequency of forbs, therefore, occurred during spring and summer when these species were most available.

Bluebunch Wheatgrass usually dominates bighorn sheep winter ranges in British Columbia, and is often considered a key management species. Our data confirm the importance of Bluebunch Wheatgrass for both the annual ($\bar{x}$ = 20.5%) and winter ($\bar{x}$ = 28.8%) diet of California Bighorn Sheep (Table 2). Nonetheless, all other forage species averaged 79.5% and 71.2% diet frequency during these same periods, respectively. These other forage species also contributed significantly to annual, herbaceous production in 1977(73.3%) and 1978 (44.1%)(Wikeem 1984).

Habitat management for California Bighorn Sheep should strive to provide a mixture of grasses, forbs, and browse. Quality habitat depends more on a complement of plant species, which provides a diversity of forage alternatives, than on dominance by a few, albeit key management species.

Acknowledgments

Research was supported in part by the Natural Sciences and Engineering Research Council of Canada. Logistic and field support were provided by The British Columbia Ministry of Environment (Fish and Wildlife Branch) and the Okanagan Game Farm. Sandra Wikeem and Reg Newman are thanked for assisting with field work and data analyses, respectively.

Literature Cited

Association of Official Analytical Chemists. 1975. Official methods of analysis. (12th edition). Association of Official Agricultural Chemists. Washington, D.C. 1094 pages.

Blood, D. A. 1967. Food habits of the Ashnola bighorn sheep herd. Canadian Field-Naturalist 81: 23–29.

Buechner, H. K. 1960. The bighorn sheep in the United States, its past, present and future. Wildlife Monograph Number 4. 174 pages.

Cook, C. W. 1972. Comparative nutritive values of forbs, grasses and shrubs. Pages 303–310 *in* Wildland shrubs — their biology and utilization. *Edited by* C. M. McKell, J. P. Blaisdell, and J. R. Goodin. U.S. Department of Agriculture, Forest and Range Experiment Station Technical Report INT-1, 1972. Ogden, Utah.

Demarchi, R. A. 1965. An ecological study of the Ashnola bighorn winter ranges. M.Sc. thesis, University of British Columbia, Vancouver. 103 pages.

Department of Animal Science. 1979. Analytical methods in animal nutrition and laboratory methods, University of British Columbia, Vancouver. 54 pages.

Ellis, J. E., J. A. Wiens, C. F. Rodell, and **J. C. Anaway.** 1976. A conceptual model of diet selection as an ecological process. Journal of Theoretical Biology 60: 93–108.

Environment Canada (Atmospheric Environment Service). 1974. Climate of British Columbia: tables of temperature and precipitation. Climatic normals 1941-

1970. British Columbia Department of Agriculture. 90 pages.

Fairbanks, W. S., J. A. Bailey, and **R. S. Cook.** 1987. Habitat use by a low-elevation semicaptive bighorn sheep population. Journal of Wildlife Management 51: 912–915.

Geist, V. 1971. Mountain sheep: A study in behavior and evolution. University of Chicago Press, Chicago and London. 382 pages.

Hanley, T. A. 1982. The nutritional basis for food selection by ungulates. Journal of Range Management 35: 146–151.

Hansen, M. C. 1982. Status and habitat preference of California bighorn sheep on Sheldon National Wildlife Refuge, Nevada. M.Sc. thesis, Oregon State University, Corvallis. 75 pages.

Heady, H. F. 1975. Rangeland management. McGraw-Hill Book Co., New York. 460 pages.

Hickey, W. O. 1978. Bighorn sheep ecology. Idaho Department of Fish and Game Project W-160-R-5. 54 pages.

Hitchcock, C. L., and **A. Cronquist.** 1973. Flora of the Pacific Northwest. University of Washington Press, Seattle. 730 pages.

Hobbs, N. T. 1982. Confidence intervals on food preference indices. Journal of Wildlife Management 46: 505–507.

Jones, F. L. 1950. A survey of the Sierra Nevada bighorn. Sierra Club Bulletin 35: 29–76.

Kelley, C. C., and **R. H. Spilsbury.** 1949. Soil surveys of the Okanagan and Similkameen Valleys, British Columbia. Report Number 3. of British Columbia Survey. Kings Printer and Controller of Stationary, Ottawa, Canada. 88 pages.

McInnis, M. L., and **M. Vavra.** 1987. Dietary relationships among feral horses, cattle, and pronghorn in southeastern Oregon. Journal of Range Management 40: 60–66.

McInnis, M. L., M. Vavra, and **W. C. Krueger.** 1983. A comparison of four methods used to determine the diets of large herbivores. Journal of Range Management 36: 302–306.

McLean, A. 1970. Plant communities of the Similkameen Valley, British Columbia, and their relationship to soils. Ecological Monographs 40: 403–424.

Morrison, D. C. 1972. Habitat utilization by mule deer in relation to cattle and California bighorn sheep in the Ashnola River Valley, British Columbia. M.Sc. thesis, University of British Columbia, Vancouver, Canada. 189 pages.

Oelberg, K. 1956. Factors affecting the nutritive value of range forage. Journal of Range Management 9: 220–224.

Oldemeyer, J. L., W. J. Barmore, and **D. L. Gilbert.** 1971. Winter ecology of bighorn sheep in Yellowstone National Park. Journal of Wildlife Management 35: 257–269.

Parker, K. W. 1951. A method for measuring trends in range condition on national forest ranges. U.S. Department of Agriculture, Forest Service, Washington, D.C. 26 pages.

Plummer, A. P. 1972. Selection. Pages 121–126 *in* Wildland shrubs — their biology and utilization. *Edited by* C. M. McKell, J. P. Blaisdell, and J. R. Goodin. U.S. Department of Agriculture, Forest and Range Experiment Station Technical Report INT-1, 1972. Ogden, Utah.

Smith, D. R. 1954. The bighorn sheep in Idaho. Its status, life history and management. Idaho Game and Fish Department Wildlife Bulletin 1. 154 pages.

Stelfox, J. G., and **D. J. Spalding.** 1974. Bighorn sheep ecology study. Vaseux-bighorn wildlife area. Canadian Wildlife Service File Number 408/10 Vaseux. 36 pages.

Stewart, S. T. 1975. Ecology of the West Rosebud and Stillwater bighorn sheep herds, Beartooth Mountains, Montana. Montana Fish and Game Department Project Numbers W-120-R-6 and R-7. 129 pages.

Strasia, C. A., M. Thorn, R. W. Rice, and **D. R. Smith.** 1970. Grazing habits, diet, and performance of sheep on alpine ranges. Journal of Range Management 23: 201–207.

Sugden, L. G. 1961. The California bighorn in British Columbia with particular reference to the Churn Creek herd. British Columbia Department of Recreation and Conservation. 58 pages.

Van Dyne, G. M., and **H. F. Heady.** 1965. Botanical composition of sheep and cattle diets on a mature annual range. Hilgardia 36: 465–492.

van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feeds. I. Preparation of fiber residues of low nitrogen content. Journal of Association of Official Agricultural Chemists 46: 825–835.

Westoby, M. 1974. An analysis of diet selection by large generalist herbivores. American Naturalist 108: 290–304.

Wikeem, B. M. 1984. Forage selection by California bighorn sheep and the effects of grazing on an Artemisia-Agropyron community in southern British Columbia. Ph.D. thesis, University of British Columbia, Vancouver, Canada. 319 pages.

Wikeem, B. M., and **M. D. Pitt.** 1987. Evaluation of methods to determine use of browse by California Mountain Sheep. Wildlife Society Bulletin 15: 430–433.

Williams, O. B. 1969. An improved technique for identification of plant fragments in herbivore feces. Journal of Range Management 22: 51–52.

Received 8 July 1991
Accepted 5 March 1992

Winter Habitat Use by Male and Female American Kestrels, *Falco sparverius*, in Southwestern Ontario

TODD W. ARNOLD[1,3] and PAMELA A. MARTIN[2,4]

[1]Department of Zoology, University of Western Ontario, London, Ontario N6A 5B7
[2]Department of Environmental Biology, University of Guelph, Guelph, Ontario N1G 2W1
[3]Present Address: Institute for Wetland and Waterfowl Research, Ducks Unlimited Canada, P.O. Box 1160, Stonewall, Manitoba R0C 2Z0
[4]Present Address: RR 4, Box 59, Saskatoon, Saskatchewan S7K 3J7

Arnold, Todd W., and Pamela A. Martin. 1992. Winter habitat use by male and female American Kestrels, *Falco sparverius*, in southwestern Ontario. Canadian Field-Naturalist 106(3): 336–341.

Throughout much of the southern United States and Mexico, wintering American Kestrels (*Falco sparverius*) exhibit sexual segregation by habitat, with females occupying areas that are relatively more open and males occupying areas that are relatively more wooded. We investigated habitat use by wintering American Kestrels in southern Ontario. Contrary to most previous studies of winter habitat use, we detected no differences in habitat selection between males and females. We attribute our results to low densities of wintering kestrels, and hence little intersexual competition for high quality (i.e. more open) habitats.

Key Words: American Kestrels, *Falco sparverius*, habitat selection, sexual dimorphism, sexual habitat segregation, southern Ontario, wintering distribution.

In many species of birds, males and females have different wintering distributions. This variation may occur on a regional scale (i.e., differential migration leading to latitudinal segregation; Ketterson and Nolan 1983), or on a local scale (i.e. habitat segregation; Koplin 1973; Morrison and With 1987; Ornat and Greenberg 1990). Male American Kestrels (*Falco sparverius*) winter farther north than females, on average, but this variation is extremely slight (Arnold 1991). However, on a local scale, kestrels often exhibit pronounced sexual segregation by habitat, with females typically occurring in more open habitats and males occupying more wooded areas (Koplin 1973; Mills 1976; Layne 1980; Stinson et al. 1981; Bohall-Wood and Collopy 1986; Meyer and Balgooyen 1987; Smallwood 1987).

Koplin (1973) suggested that habitat segregation in kestrels was an adaptation to reduce intersexual competition for food resources, but it is difficult to see how such behavior could evolve by natural selection unless pairs maintained permanent year-round territories. Mills (1976) suggested that winter habitat segregation was a secondary consequence of reversed sexual dimorphism in body size (male kestrels weigh 8–14% less than females; Dunning 1984; Smallwood 1987). Smaller body size could render males subordinate to females, and thereby force them to accept inferior winter habitats. Mills also thought that natural selection might secondarily favor males that preferentially selected less suitable habitats in order to avoid territorial confrontations with dominant females. Stinson et al. (1981) also believed that males preferentially selected more wooded habitats, but did not consider these areas to be inferior to the more open areas used by females. Smallwood (1988) showed that male and female kestrels were equally adept at defending their individual winter territories against opposite-sex intruders, and he suggested that sexual habitat segregation occurs because adult females arrive first on the wintering grounds and pre-empt the best quality territories. Smallwood hypothesized that most adult males arrive later on the wintering grounds due to timing constraints associated with wing molt, and that these males must therefore establish territories on any remaining unclaimed habitat, which is likely to be inferior habitat in areas of high kestrel densities. For kestrels arriving synchronously on his southcentral Florida study area, Smallwood (1988) observed no differences in habitat quality between males and females. Thus, according to Smallwood's hypothesis, adult females are dominant over adult males, but this dominance is due to earlier arrival on the wintering grounds and greater site familiarity, not due to greater body size. The above-mentioned studies that demonstrated sexual habitat segregation in kestrels were conducted in the southern United States (Florida, Georgia, Texas, Arizona, and California) or Mexico, where densities of wintering kestrels are high (Root 1988), populations are composed primarily of migrants (Bohall-Wood and Collopy 1986), and quality habitats are likely to be saturated (Smallwood 1988).

We studied habitat selection by male and female kestrels wintering in southwestern Ontario. This area represents the northern limit of the kestrel's wintering range (Root 1988), and winter population densities are much lower than in the southern United

States (Root 1988). We predicted that if winter habitat segregation in kestrels was a proximate outcome of habitat saturation by socially dominant females (according to either Mills' or Smallwood's hypothesis), then low kestrel densities on our study area would allow males to settle in vacant habitats similar to those used by females. However, if habitat selection by males was part of an innate preference for more wooded habitats, then sexual differences in habitat use should be apparent despite low kestrel densities.

Study Area and Methods

Roadside surveys were conducted within a 30-km radius of Stratford, Ontario (43°19'N, 80°59'W). The landscape is comprised primarily of open agricultural areas (e.g., corn, small grain, hay, and dairy pastures), but deciduous woodlots, shelterbelts, apple orchards, and farm yards provide areas of wooded cover. Kestrel censuses were conducted from 16 October to 27 February in the winters of 1987–1988 and 1988–1989. We drove secondary roads in a slow (≈ 60 km/h) systematic fashion and kept watch for perched or flying kestrels. Most roadways were sampled only once each winter, but for those roadways that were censused more than once, at least one month elapsed before transects were resampled. Thus, although we may have collected more than one data point from some kestrels, we regard each observation as statistically independent. When we observed a kestrel, we determined its sex using binoculars or a spotting scope and then collected habitat data with reference to its perching site. Kestrels first observed in hovering flight were treated as if "perching" in air, but birds first observed while making directional flights were allowed to settle before we began collecting data. Perched kestrels invariably flushed as a result of our activities, and we observed their flightpath to record their next perching site.

We recorded the following data for each perched kestrel: sex, lateral distance to perch site from the center of the road, initial and secondary perch type, height of initial perch, habitat composition within a 30-m radius of the initial perch site, dominant land-use on both sides of the road, width of roadside right-of-way on both sides of the road, and distances from the initial perch site to the nearest powerline, tree, shrub, fence, building, and woodlot. Trees were defined as woody vegetation > 4 m tall, shrubs as woody vegetation 1–4 m tall, and woodlots as wooded areas > 0.5 ha (single row shelter-belts were not included). Distances were estimated using a Ranging® 1200 prismatic rangefinder (50–1000 m) or by pacing (< 50 m). Perch sites were assigned to four categories: (1) powerlines or powerpoles, (2) trees or shrubs, (3) other perches (including fences, buildings, traffic signs, and the ground), and (4) hovering flight. Habitat composition was determined by visually estimating the percent coverage of seven land-use types within a 30-m radius of the perch site; these included: (1) unvegetated roadway, (2) idle areas (i.e., roadside right-of-ways, fencerows, waterways, and old-field habitats), (3) wooded areas (woodlots, orchards, or scrub-shrub), (4) human habitations (buildings and mowed or landscaped yards), (5) pastures and haylands, (6) fall-plowed croplands with little or no residual vegetation, and (7) cropland (standing crops, unplowed stubble, and autumn-seeded grain fields). Tree and shrub densities within a 30-m radius were recorded as: 0, none present; 1, one or two stems present; 2, three to 10 stems present; 3, > 10 stems up to 50% areal coverage; and 4, > 50% areal coverage. Categories 3 and 4 were pooled for statistical analysis due to low frequencies.

Habitat data were also collected at "random" sites; these were selected systematically using the vehicle odometer (i.e., every 5.0 miles on days when we collected these data). Because of the arbitrariness that would have been involved in selecting a random perch site, we measured distances to habitat features from the center of the road. We did not record habitat composition within a 30-m radius at random sites because our circle would have been dominated by roadway.

Statistical comparisons were conducted between kestrel perches and random sites, and between male and female perch sites, using analysis of variance for continuous variables and contingency tables (G-tests) for categorical variables (PROC GLM and PROC FREQ, SAS Institute Inc. 1985). Because a large number of continuous variables were compared, there was a high likelihood of observing one or more Type I errors. We therefore used multivariate analysis of variance (MANOVA) to test the null hypothesis of no overall habitat differences between groups.

Results

We drove 1168 km of transects on 24 days and recorded data from 109 random sites and 146 kestrel perches (57 males, 74 females, and 15 of undetermined sex). Sex ratios were similar between winters ($G = 0.30$, 1 d.f., $P > 0.90$). Observed kestrel density was 0.128 birds per km and did not vary between winters ($F_{1,22} = 0.81$, $P = 0.38$) or among months ($F_{4,19} = 1.88$, $P = 0.16$). Characteristics of random sites differed significantly from those of kestrel perches (Table 1: MANOVA, $P < 0.0001$). This difference was due primarily to proximity of powerlines, which kestrels selected overwhelmingly as perch sites (see Table 3), and to areas of dense trees, which kestrels avoided (Table 1). With distance to powerlines and tree density excluded, the MANOVA was no longer significant ($F_{7,237} = 1.91$, $P =$

TABLE 1. Habitat characteristics of perch sites used by wintering American Kestrels in southwestern Ontario, in comparison with random sites.

Variable	Kestrels $\bar{x}$	Kestrels (95% CI)	Random sites $\bar{x}$	Random sites (95% CI)	F	P
Tree density	0.54	(0.38 - 0.70)	0.77	(0.58 - 0.96)	4.29	0.04
Shrub density	0.65	(0.47 - 0.83)	0.84	(0.64 - 1.04)	2.42	0.12
Right-of-way width	5.5	(4.7 - 6.2)	4.6	(3.9 - 5.5)	2.05	0.15
Nearest powerline	4.0	(2.5 - 6.1)	19.0	(14.0 - 25.5)	31.91	0.0001
Nearest tree	30.6	(23.4 - 40.3)	36.2	(29.6 - 44.7)	0.83	0.36
Nearest shrub	32.9	(26.6 - 40.4)	30.6	(25.2 - 37.1)	0.19	0.67
Nearest fence	16.4	(12.1 - 22.5)	24.1	(19.3 - 30.1)	3.43	0.07
Nearest building	137	(120 - 153)	124	(105 - 146)	0.87	0.35
Nearest woodlot	256	(219 - 303)	239	(194 - 274)	0.49	0.48
MANOVA	–		–		8.76	0.0001

Sample sizes were 143 for kestrel sites and 107 for random sites. Tree and shrub density are based on cover codes (see methods), all other variables are in m. Distances were transformed [$\log_{10}$ (X + 1)] for statistical analysis; means and confidence intervals were calculated from log-transformed values and then back-transformed.

0.07). The near-significance of this second test was apparently due to proximity of perched kestrels to fences (Table 1). However, fences were rarely used as perches (see Table 3), and distance to nearest fence was not strongly correlated with distance to nearest powerline or with tree density ($r^2 < 0.02$ for each), so we suspect that this test result was spurious. Kestrels were detected more often than expected near idle areas, pastures and haylands, and crop areas; they were observed less often than expected near inhabited areas, wooded areas, and plowed fields. However, these slight differences in land use between random sites and kestrel sites were not significant (Table 2).

Male and female perch sites did not differ in surrounding land use (Table 2) or perch type (Table 3), or with respect to 18 habitat composition and spatial proximity characteristics (Table 4).

Discussion

We obtained no evidence of habitat segregation between male and female American Kestrels. Of 22 habitat variables we examined, none varied significantly between male and female perch sites ($P \geq 0.13$). This is in marked contrast to most previous studies of habitat segregation in kestrels (see Introduction), but is consistent with two other studies (Sferra 1984; Toland 1987). To examine possible correlates of this difference, we summarized various attributes of the 12 studies that recorded sexual habitat segregation and the three studies that failed to record it (Table 5). Sample sizes in the three studies without habitat segregation appeared to be sufficient, as evidenced by much smaller samples in several of the studies that did record significant habitat segregation (Table 5). Thus, failure to document habitat segregation was not likely due to Type II statistical error (i.e., failing to detect a true difference). The three studies without habitat segregation were all from the north-central portion of the wintering range, and were also characterized by relatively low kestrel densities (Table 5). Interestingly, Bildstein's (1987) study in south-central Ohio found sexual differences in kestrel use of farmsteads and hilly ter-

TABLE 2. Dominant land use (% of all observations) at random sites, and at sites used by American Kestrels.

Land use	Random sites	Kestrels		
		Both sexes*	Males	Females
Idle	2.8	4.8	7.0	4.1
Wooded	4.6	2.1	1.8	2.7
Farmyard/urban	9.2	5.5	7.0	5.4
Pasture/hayland	25.7	31.5	22.8	33.8
Fall plowed	43.1	39.0	45.6	35.1
Cropland	14.7	17.1	15.8	18.9
n	109	146	57	74

*Includes 15 kestrels of undetermined gender.

There were no differences between random sites and kestrel sites (both sexes combined) (G = 4.36, 5 d.f., $P = 0.50$), or between male and female sites (G = 3.22, 5 d.f., $P = 0.66$).

TABLE 3. Comparison of perch sites used by male and female American Kestrels (data are % use).

	First perches[1]		Second perches[1]	
Perch type	Males	Females	Males	Females
Power lines or poles	66.7	63.5	58.0	51.7
Trees or shrubs	8.8	16.2	22.0	20.0
Other perches[2]	8.8	5.4	14.0	23.3
Hovering flight	15.8	14.9	6.0	5.0
n	57	50	74	60

[1] First perches represent original observation sites for each kestrel; kestrels moved to second perches after being flushed from first perches.

[2] Includes buildings, fences, traffic signs, the ground, and other miscellaneous sites.

Male and female perch sites did not differ (first perches: G = 2.02, 3 d.f., $P = 0.57$; second perches: G = 1.58, 3 d.f., $P = 0.66$), but first perches differed from second perches for both sexes combined (G = 14.75, 3 d.f., $P = 0.002$).

rain, but did not find sexual differences in selection of land-use types, vegetation types, or field sizes, or in the proximity of perched kestrels to woodlots and tree-rows (i.e., differences were not observed in the variables most typically associated with differential habitat use by male and female kestrels). Thus, Bildstein's results are more similar to the studies that did not document sexual habitat segregation, and this interpretation of his results therefore strengthens the dichotomies between northern and southern studies, and between studies with low and high kestrel densities (see Table 5). We believe that these two factors are related: that the north-south dichotomy arises primarily from differences in kestrel density (Root 1988), and hence, saturation of preferred kestrel habitats in the south (e.g., Smallwood 1988), but not in the north. Our results therefore provide indirect support to Smallwood's (1988) hypothesis that sexual habitat segregation in kestrels results from habitat saturation combined with female dominance (through prior residence). We regard these conclusions as tentative, and we believe that additional studies of habitat segregation are needed from the northern portion of the kestrel's wintering range, and from southern areas with low kestrel densities.

Kestrels are more difficult to observe in wooded habitats than in open habitats (see Millsap and LeFranc 1988), which introduces unavoidable bias into studies of winter habitat selection. If males use wooded habitats more frequently than females, but cannot easily be observed while using them, then it would be very difficult to document sexual habitat segregation even when it existed. Although we rec-

TABLE 4. Comparison of habitat characteristics at perch sites used by male and female American Kestrels.

	Males		Females			
Variable	$\bar{x}$	(95% CI)	$\bar{x}$	(95% CI)	F	P
Lateral distance	14.1	(10.7 - 18.7)	19.0	(14.6 - 24.2)	2.37	0.13
Perch height	6.4	(5.6 - 7.3)	6.4	(5.7 - 7.0)	0.03	0.86
Tree density	0.56	(0.33 - 0.79)	0.53	(0.34 - 0.72)	0.05	0.82
Shrub density	0.60	(0.37 - 0.83)	0.76	(0.53 - 0.99)	0.94	0.33
Right-of-way width	5.3	(4.2 - 6.6)	5.3	(4.3 - 6.4)	0.00	0.95
Nearest powerline	3.0	(1.3 - 6.0)	3.5	(1.7 - 6.3)	0.11	0.74
Nearest tree	36.2	(24.7 - 52.7)	29.9	(20.2 - 44.2)	0.42	0.52
Nearest shrub	37.0	(27.2 - 49.5)	28.5	(20.7 - 39.3)	1.37	0.24
Nearest fence	19.9	(12.1 - 31.7)	13.8	(8.8 - 21.4)	1.15	0.29
Nearest building	137	(112 - 167)	140	(119 - 166)	0.02	0.88
Nearest woodlot	268	(202 - 351)	256	(206 - 320)	0.06	0.81
% roadway	15.0	(12.5 - 17.5)	15.1	(12.8 - 17.4)	0.00	0.95
% idle	20.8	(16.4 - 25.2)	18.4	(14.8 - 22.0)	0.73	0.39
% wooded	2.8	(0 - 6.5)	2.5	(0 - 5.6)	0.02	0.90
% farmyard/urban	6.0	(1.7 - 10.3)	5.0	(1.3 - 8.7)	0.13	0.72
% pasture/hayland	17.7	(10.7 - 24.7)	21.2	(14.4 - 28.0)	0.50	0.48
% fall plowed	27.7	(19.2 - 36.2)	25.5	(18.6 - 32.4)	0.17	0.68
% cropland	9.7	(4.9 - 14.5)	12.7	(7.0 - 18.4)	0.60	0.44
MANOVA	–		–		0.69	0.82

Sample size equals 56 for males and 73 for females. Units, means, and confidence intervals as in Table 1.

TABLE 5. Summary of studies on sexual habitat segregation in wintering American Kestrels.

Location	Segregation reported?	Latitude	Number of kestrels[a]		Number of habitat variables[b]	Kestrel densities[c]			Sources[d]
			Males	Females		Study	CBC	Root	
SC Ontario	N	43°19'	57	74	22	0.13	0.16	1	This study; SF ON
NC California	Y	39°42'	15	28	1(3)	1.52	0.57	4	J. H. Snowden, pers. comm.; CO CA
SC Ohio	Y[e]	39°28'	425	547[f]	6	0.11[g]	0.31	3	Bildstein 1987; KI OH
NW California	Y	39°03'	196	477	1(3)	0.46	0.70	3	Koplin 1973; MN CA
NC Missouri	N	38°53'	3179	3179	1(7)	–	0.12	2	Toland 1987; CO MO
C Kentucky	N	37°38'	212	153	1(6)	0.16	0.29	2	Sferra 1984; DA KY
SW Colorado[h]	Y	37°14'	35	51	1(5)	–	0.03	1	Mills 1976; DU CO
WC California[i]	Y	36°48'	1471	1727	1(11)	–	0.61	4–5	Meyer and Balgooyen 1987; HO CA
S Arizona	Y	32°15'	121	159	1(5)	0.12	0.11	1–2	Mills 1976; AV AZ
E Georgia	Y	31°38'	99	75	1(3)	–	0.12	2	Stinson et al. 1981; SC GA
SC California	Y	31°31'	4	19	1(2)	–	0.85	3	Mills 1976; SS CA
NC Florida	Y	28°30'	405	763	1(9)	3.57	0.29	3	Bohall-Wood and Collopy 1986; GA FL
SC Florida	Y	27°00'	54	116	14	0.82	0.52	4	Smallwood 1987, 1988; OR FL
SC Texas	Y	25°56'	128	147	2	0.15	0.28	3–4	Mills 1976; BV TX
WC Mexico	Y	21°34'	12	9	1(2)	–	0.37	–	Mills 1976; SB MX

[a] Number of observations. In some studies, these were obtained from much smaller numbers of kestrels (e.g. $n = 6$ and 6; Toland 1987).

[b] Number of variables tested. When only 1 categorical variable was used (land-use type), the number of land-use categories is given in parentheses.

[c] Kestrel densities: "Study" is density (birds/km) reported by the authors of the habitat segregation study, "CBC" is density of kestrels (birds/party km) recorded in the nearest 88th Christmas Bird Count, "Root" is a quintile index of winter kestrel abundance (1 = least abundant, 5 = most abundant) in the approximate area of the habitat segregation study, as interpolated from Root's (1988) analysis of CBC data.

[d] First source (standard reference) is the study documenting habitat use by male and female kestrels. Second source is the 4 letter abbreviation for the Christmas Bird Count data used to compute CBC kestrel density (*American Birds* 1988, except CO CA from *American Birds* 1987).

[e] No differences in land-use type, vegetation type, field size, or proximity to woodlots and tree-rows.

[f] Assuming 44% males and 972 sexed kestrels (Bildstein 1987: Table 16, Figure 10).

[g] Estimated from data in Bildstein 1987: Figure 5.

[h] Includes NW New Mexico and NE Arizona.

[i] Observations were obtained throughout the year.

ognize this as an important bias, we doubt that it would vary substantially between northern and southern wintering areas. Although kestrels that we observed were likely to be a non-random sample of the most-visible individuals, we also followed these individuals to their second perch site after we flushed them. We could usually identify what kind of perch the kestrel landed on, even if the bird was hidden from our view after landing. There was, however, no sexual difference in choice of second perches, even though there was evidence of visibility bias (Table 3: second perches were more likely to include trees, shrubs, and "others", whereas first perches were more likely to include powerlines or hovering flight). We therefore conclude that if sexual habitat segregation occurs in kestrels, it is likely to be underestimated due to the effects of visibility bias; however, this bias cannot easily explain our failure to detect habitat segregation, relative to other studies where visibility bias must also have occurred.

We suspect that many of the kestrels that winter in southern Ontario may be remaining on their breeding territories from the previous summer. Many of these birds also appear to be maintaining loose pair bonds throughout the winter (whenever two kestrels were sighted in close proximity, one was male and one was female; see also Mills 1975). If a large proportion of northerly-wintering kestrels are in fact maintaining year-round territories or pair bonds, it would probably preclude sexual habitat segregation at anything other than a very fine scale. Clearly, studies must be conducted on colour-marked populations throughout the breeding and wintering seasons to clarify these issues.

Finally, we note that most of southern Ontario has been deforested, and there is very little wooded habitat remaining. However, we do not believe that the failure of male kestrels to use wooded habitats in our study was due to the low availability of this habitat type, because some wooded habitat was available along all transects we used. If males had preferred these habitats, we believe that our data would have indicated this. Our inability to document differential habitat use among male and female kestrels on our study area does not preclude the existence of innate sexual habitat preferences elsewhere in the wintering range, but it does suggest that such preferences, if they occur, are context specific (i.e. that they occur only among first-year, or migratory, birds).

Literature Cited

Arnold, T. W. 1991. Geographic variation in sex ratios of wintering American Kestrels *Falco sparverius*. Ornis Scandinavica 22: 20–26.

Bildstein, K. L. 1987. Behavioral ecology of Red-tailed Hawks (*Buteo jamaicensis*), Rough-legged Hawks (*Buteo lagopus*), Northern Harriers (*Circus cyaneus*), and American Kestrels (*Falco sparverius*) in south central Ohio. Ohio Biological Survey, Biological Notes Number 18.

Bohall-Wood, P., and **M. W. Collopy.** 1986. Abundance and habitat selection of two American Kestrel subspecies in north-central Florida. Auk 103: 557–563.

Dunning, J. B., Jr. 1984. Body weights of 686 species of North American birds. Western Bird Banding Association, Monograph Number 1.

Ketterson, E. D., and **V. Nolan, Jr.** 1983. The evolution of differential migration. Pages 357–402 *in* Current ornithology, volume 1. *Edited by* R. F. Johnston. Plenum Press, New York.

Koplin, J. R. 1973. Differential habitat use by sexes of American Kestrels wintering in Northern California. Raptor Research 7: 39–42.

Layne, J. N. 1980. Trends in numbers of American Kestrels on roadside counts in southcentral Florida from 1968 to 1976. Florida Field Naturalist 8: 1–10.

Meyer, R. L., and **T. G. Balgooyen.** 1987. A study and implications of habitat separation by sex of wintering American Kestrels (*Falco sparverius*). Pages 107–123 *in* The ancestral kestrel. *Edited by* D. M. Bird and R. Bowman. Raptor Research Report Number 6.

Mills, G. S. 1975. A winter population study of the American Kestrel in central Ohio. Wilson Bulletin 87: 241–247.

Mills, G. S. 1976. American Kestrel sex ratios and habitat separation. Auk 93: 740–748.

Millsap, B. A., and **M. N. LeFranc, Jr.** 1988. Road transect counts for raptors: how reliable are they? Journal of Raptor Research 22: 8–16.

Morrison, M. L., and **K. A. With.** 1987. Interseasonal and intersexual resource partitioning in Hairy and White-headed woodpeckers. Auk 104: 225–233.

Ornat, A. L., and **R. Greenberg.** 1990. Sexual segregation by habitat in migratory warblers in Quintana Roo, Mexico. Auk 107: 539–543.

Root, T. 1988. Atlas of wintering North American birds. University of Chicago Press, Chicago.

SAS Institute Inc. 1985. SAS user's guide: statistics. Version 5 edition. SAS Institute Inc., Cary, North Carolina.

Sferra, N. J. 1984. Habitat selection by the American Kestrel (*Falco sparverius*) and Red-tailed Hawk (*Buteo jamaicensis*) wintering in Madison County, Kentucky. Raptor Research 18: 148–150.

Smallwood, J. A. 1987. Sexual segregation by habitat in American Kestrels (*Falco sparverius*) wintering in southcentral Florida: vegetative structure and responses to differential prey availability. Condor 89: 842–849.

Smallwood, J. A. 1988. A mechanism of sexual segregation by habitat in American Kestrels (*Falco sparverius*) wintering in south-central Florida. Auk 105: 36–46.

Stinson, C. H., D. L. Crawford, and **J. Lauthner.** 1981. Sex differences in winter habitat of American Kestrels in Georgia. Journal of Field Ornithology 52: 29–35.

Toland, B. R. 1987. The effect of vegetative cover on foraging strategies, hunting success and nesting distribution of American Kestrels in central Missouri. Journal of Raptor Research 21: 14–20.

Received 9 October 1991
Accepted 25 February 1992

The Vascular Plant Flora of Rankin Inlet, District of Keewatin, Northwest Territories

J. B. Korol

Department of Crop Science and Plant Ecology, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

Korol, J. B. 1992. The vascular plant flora of Rankin Inlet, District of Keewatin, Northwest Territories. Canadian Field-Naturalist 106(3): 342–347.

One hundred and sixty-two full species of vascular plants collected by the author during the summer of 1988, are reported from the Rankin Inlet area, District of Keewatin. *Braya purpurescens*, *Descurainia sophioides*, *Saxifraga tenuis* and *Astragalus eucosmus* are new records for the continental part of the District of Keewatin. *Pleuropogon sabinii* is the second record for the continental Northwest Territories.

Key Words: Vascular flora, *Braya purpurescens*, *Descurainia sophioides*, *Saxifraga tenuis*, *Astragalus eucosmus*, Rankin Inlet, District of Keewatin.

Rankin Inlet is located in the District of Keewatin at 62°48'N, 92°05'W on the west shore of Hudson Bay (see Figure 1). During a 66 day period (7 June to 11 August, 1988) a collection of vascular plants was made by the author in the vicinity of Rankin Inlet. The collection was made to gain personal knowledge of the flora of the area. The author was in the study area assisting with an unrelated study of the population and feeding ecology of Peregrine Falcons (*Falco peregrinus*) which was funded by a grant from the Northern Scientific Training Program. Previous records of the flora of the area are limited (Macoun 1911; Rowe 1968; unpublished data compiled by V. L. Harms; and Rowe et al. 1977). It is presumed that all previous verified species records have been mapped by Porsild and Cody (1980). The purpose of this paper is to report the plants found during the 1988 survey, in order to better document the components of the flora of Rankin Inlet.

Study Area

Collections were made from an area of approximately 180 km^2, which included all mainland within 10 km of Rankin Inlet townsite, south of the Meliadine River and the following islands: Barrier, Butress, Panorama, Thomson, Falstaff and Marble (Figure 1). The terrain around Rankin Inlet is generally of low-relief with altitudes less than 50 m above sea level. Wright (1955, in Rowe et al. 1977) states that the predominant Precambrian rocks outcropping on the uplands around Rankin Inlet are greenstones, with lesser quartzite, conglomerate, dolomite and schist. Dominant vegetation of outcrop areas included saxifrages, mosses and ferns. Eskers, ridges and the major rivers are oriented in a northwest to southeast direction. The well drained sand/gravel soils associated with these landforms typically supported several species of Whitlow-Grass, Blue Grasses, Sea Lime Grass and Crowberry. Vegetation communities associated with the better drained tundra areas were dominated by ericaceous shrubs, sedges and Broad-leaved Willow-herb. Drainage patterns are poorly developed and lakes and ponds are numerous. Louseworts, willows and sedges were among the most characteristic vegetation of poorly drained tundra sites. Sedges and cottongrasses were well represented in lake and pond margin habitats. Snow remained well into June of 1988 and Hudson Bay was ice covered until mid-July. Winds were frequent and strong, usually from the north or northwest. The permafrost near Rankin Inlet extends approximately 300 m into the ground (Rowe et al. 1977).

Methods

This survey was carried out during the summer of 1988. During routine field work an effort was made to collect specimens of all vascular plants found in the area. Boats, all terrain cycles and snowmobiles provided access to a number of different habitats on the mainland and islands, including rock outcrops, tundra, wetlands, tidal areas and aquatic habitats. A total of 162 species (with an additional two subspecies and one variety) of vascular plants were collected. This represents approximately 70% of the flora that one could expect in the Rankin Inlet area based on the range maps found in Porsild and Cody (1980). In perspective, the number of species presently reported for Rankin Inlet compares quite well with the nearly 160 taxa that Saville and Calder (1952) indicated were listed by Polunin from Chesterfield Inlet, located about 100 km to the north. The collection numbers cited below are those of the author. Specimens have been deposited in the W. P. Fraser Herbarium at the University of Saskatchewan (SASK).

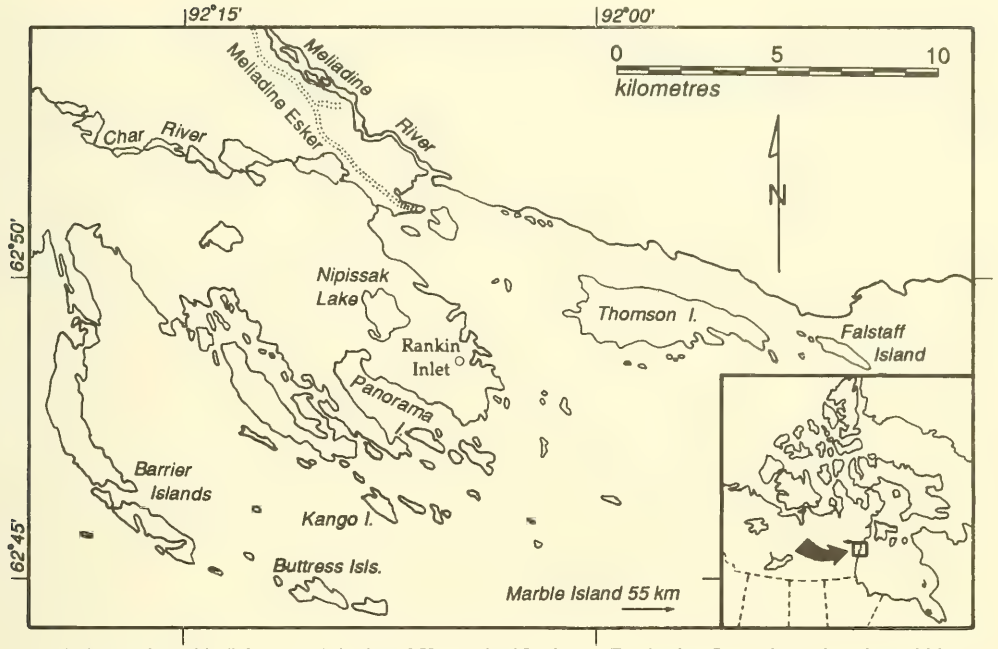


FIGURE 1. Map of Rankin Inlet area, District of Keewatin, Northwest Territories. Inset shows location within northern Canada.

Annotated Species List

A list of vascular plants collected by the author in 1988 follows. The list of 165 taxa includes two subspecies of Water Sedge (*Carex aquatilis*), two subspecies of Wooly Willow (*Salix lanata*) and two varieties of Tufted Saxifrage (*Saxifraga caespitosa*). All plant names are based on Porsild and Cody (1980) with exceptions noted in the species accounts. It is recognized that some genera (such as *Melandrium*) have recently undergone taxonomic revision (Brunton 1981) but since the emphasis of this paper is not on nomenclature, names from one source are used merely to be consistent. Common names are those currently used at the W. P. Fraser Herbarium and originate from numerous sources.

POLYPODIACEAE

Cystopteris fragilis (L.) Bernh., Fragile Fern, 58. Circumpolar.

Dryopteris fragrans (L.) Schott., Fragrant Shield Fern, 4. Circumpolar.

Woodsia alpina (Bolton) S.F. Gray, Northern Woodsia 44; 46; 65. Circumpolar.

W. glabella R. Br., Smooth Woodsia, 62. Circumpolar.

EQUISETACEAE

Equisetum arvense L., Common Horsetail, 143. Circumpolar.

E. variegatum Schleich., Variegated Horsetail, 162. Circumpolar.

LYCOPODIACEAE

Lycopodium selago L., Mountain Club-Moss, 24. Circumpolar.

POTAMOGETONACEAE

Potamogeton filiformis Pers., Filiform Pondweed, 208. Circumpolar.

GRAMINAE

Agropyron violaceum (Hornem.) Lange ssp. *violaceum*, Violet Wheat Grass, 173. Circumpolar.

Alopecurus alpinus J.E. Smith, Alpine Foxtail, 64; 86. Circumpolar.

Arctagrostis latifolia (R. Br.) Griseb. ssp. *latifolia*, Polar Grass, 118; 130. Circumpolar.

Arctophila fulva (Trin.) Rupr., Pendent Grass, 174; 221. Circumpolar.

Calamagrostis deschampsioides Trin., Reed-Bentgrass, 176. Circumpolar.

Deschampsia caespitosa (L.) Beauv., Tufted Hair Grass, 154. Circumpolar.

Dupontia fisheri R. Br., Tundra Grass, 181. Circumpolar. Although Porsild and Cody illustrate two rather distinct subspecies of this grass, the material fits neither of these and was therefore not identified to subspecies.

Elymus arenarius L. ssp. *mollis* (Trin.) Hulten, Sea Lime Grass, 146. Circumpolar.

Festuca brachyphylla Schultes, Alpine Fescue, 136. Circumpolar.

Hierochloe alpina (Sw.) R. & S., Alpine Sweet Grass, 18; 31. Circumpolar.
H. pauciflora R. Br., Few-flowered Sweet Grass, 81. North American Endemic.
Pleuropogon sabinii R. Br., Semaphore Grass, 115; 222. Amphi-Atlantic.
Poa alpigena (Fr.) Lindm., Alpine Blue Grass, 84; 129. Circumpolar.
P. alpina L., Alpine Blue Grass, 163. Circumpolar.
P. arctica R. Br., Arctic Blue Grass, 135. Circumpolar.
P. flexuosa Sm., Flexuous Blue Grass, 85; 163. Amphi-Atlantic.
P. glauca M. Vahl, Greenland Blue Grass, 206. Circumpolar.
Puccinellia deschampsioides Th. Sør., Deschampsia-like Alkali-grass, 210. North American Endemic.
P. langeana (Berl.) Th. Sør., Small Goose Grass, 178. North American Endemic.
P. phryganodes (Trin.) Scribn. & Merr., Small Weeping Alkali-grass, 213. Circumpolar.
Trisetum spicatum (L.) Richt., Spike Trisetum, 197. Circumpolar.

CYPERACEAE

Carex aquatilis Wahlenb. var. *aquatilis*, Water Sedge, 119. Circumpolar.
C. aquatilus Wahlenb. var. *stans* (Drej.) Boott, Upright Water Sedge, 187; 189. Circumpolar.
C. atrofusca Schk., Dark-brown Sedge, 120; 158. Circumpolar.
C. bigelowii Torr., Stiff Sedge, 90; 204. Amphi-Atlantic.
C. capillaris L. ssp. *capillaris*, Hair-like Sedge, 212. Circumpolar.
C. glareosa Wahlenb. var. *amphigena* Fern., Clustered Sedge, 168. Circumpolar.
C. maritima Gunn., Seaside Sedge, 150. Circumpolar.
C. membranacea Hook., Fragile-seeded Sedge, 89; 91; 122; 159; 186. North American Endemic.
C. misandra R. Br., Nodding Sedge, 227. Circumpolar.
C. physocarpa Presl, Bubble Sedge, 140. Amphi-Beringian.
C. rariflora (Wahlenb.) Sm. var. *rariflora*, Scant Sedge, 190. Circumpolar.
C. rupestris All., Rock Sedge, 53. Circumpolar.
C. saxatilis L. var. *rhomalea* Fern., Rocky-ground Sedge, 131. North American Endemic.
C. scirpoidea Michx., Rush-like Sedge, 27; 66. North American Endemic.
C. subspathacea Wormskj., Wide-bracted Salt Sedge, 132. Circumpolar.
C. ursina Dew., Bear-like Sedge, 211. Circumpolar.
C. vaginata Tausch, Sheathed Sedge, 92; 188. Circumpolar.
Eriophorum angustifolium Honck., Tall Cotton-grass, 48; 67. Circumpolar.
E. brachyantherum Trautv., Close-sheathed Cotton-grass, 205. Circumpolar.
E. callitrix Cham., Beautiful Cotton-grass, 56; 80. Circumpolar.
E. scheuchzeri Hoppe, One-spike Cotton-grass, 126. Circumpolar.
E. vaginatum L., Sheathed Cotton-grass, 98. Circumpolar.
Scirpus caespitosus L. ssp. *austriacus* (Pallas) Asch. & Graeb., Tufted Bulrush, 141. Circumpolar.

JUNCACEAE

Juncus albescens (Lange) Fern., White Rush, 164. North American Endemic.
J. arcticus Willd., Arctic Rush, 88. Amphi-Atlantic.
J. biglumis L., Two-glumed Rush, 201. Circumpolar.
J. castaneus Smith, Chestnut Rush, 159; 160. Circumpolar.
Luzula confusa Lindebl., Northern Wood-rush, 70. Circumpolar.
L. nivalis (Laest.) Beurl. var. *nivalis*, Arctic Wood-rush, 198. Circumpolar.
L. wahlenbergii Rupr., Mountain Wood-rush, 142. Circumpolar.

LILIACEAE

Tofieldia coccinea Richards., Northern False Asphodel, 223. Circumpolar.
T. pusilla (Michx.) Pers., Small False Asphodel, 103. Circumpolar.

SALICACEAE

Salix alaxensis (Anderss.) Cov., Alaska Willow, 12. Amphi-Beringian.
S. arctica Pall., Arctic Willow, 9; 37. Circumpolar.
S. arctophila Cockerell, Trailing Willow, 10. North American Endemic.
S. fullertonensis Schneid., Fullerton's Willow, 123. North American Endemic.
S. fuscescens Anderss., Alaska Bog Willow, 121; 217. Amphi-Beringian.
S. herbacea L., Least Willow, 35. Amphi-Atlantic.
S. lanata L. ssp. *calcicola* (Fern. & Weig.) Hult., Lime-loving Wooly Willow, 8; 13; 124. North American Endemic.
S. lanata L. ssp. *richardsonii* (Hook.) Skvortsov, Richardson's Willow, 11; 149. Amphi-Beringian.
S. planifolia Pursh, Flat-leaved Willow, 175. North American Endemic.
S. reticulata L., Net-veined Willow, 36. Circumpolar.

BETULACEAE

Betula glandulosa Michx., Glandular Dwarf Birch, 74. North American Endemic.

POLYGONACEAE

Oxyria digyna (L.) Hill, Mountain Sorrel, 16. Circumpolar.
Polygonum viviparum L., Alpine Bistort, 94. Circumpolar.

CARYOPHYLLACEAE

Arenaria humifusa Wahlenb., Low Sandwort, 199. Amphi-Atlantic.

Cerastium alpinum L., Alpine Chickweed, 41. Amphi-Atlantic.

Honckenya peploides (L.) Ehrh. var *diffusa* (Hornem.) Mattf., Seabeach-Sandwort, 192; 218. Circumpolar.

Melandrium affine J. Vahl, Arctic Campion, 109. Circumpolar.

M. apetalum (L.) Fenzl ssp. *arcticum* (Fr.) Hult., Apetalous Campion, 151. Circumpolar.

Minuartia rubella (Wahlenb.) Hiern., Boreal Sandwort, 69. Circumpolar.

Silene acaulis L. ssp. *acaulis*, Moss-Campion, 71. Circumpolar.

Stellaria edwardsii R.Br., Edward's Starwort, 51. Circumpolar.

S. humifusa Rottb., Low Starwort, 133. Circumpolar.

S. laeta Richards., Bright Starwort, 165B. North American Endemic.

S. monantha Hult., Long-stalked Starwort, 20; 125; 165A. North American Endemic.

RANUNCULACEAE

Ranunculus aquatilis L., var. *subrigidus* (W.B. Drew) Breitung, White Water-buttercup, 229. North American Endemic.

R. cymbalaria Pursh, Northern Seaside Buttercup, 179. Circumpolar.

R. gmelinii DC., Small Yellow Water-crowfoot, 220. Amphi-Beringian.

R. hyperboreus Rottb., Boreal Buttercup, 148. Circumpolar.

R. pallasii Schlecht., Pallas' Buttercup, 290. Circumpolar.

R. pedatifidus Sm. var. *leiocarpus* (Trautv.) Fern., Northern Buttercup, 40. Circumpolar.

PAPAVERACEAE

Papaver radicatum Rottb., Arctic Poppy, 207. Circumpolar. Found by the author only on Marble Island in Hudson Bay approximately 55 km east of Rankin Inlet.

CRUCIFERAE

Arabis arenicola (Richards.) Gel., Arctic Rock-Cress, 23; 87. North American Endemic.

Braya purpurascens (R. Br.) Bunge, Low Braya, 156. Circumpolar.

Cardamine bellidifolia L., Alpine Bitter Cress, 184. Circumpolar.

C. digitata Richards., Northern Bitter Cress., 77. Amphi-Beringian.

C. pratensis L., Meadow Bitter Cress, 157. Circumpolar.

Cochlearia officinalis L., Scurvy-Grass, 172. Circumpolar.

Descurainia sophioides (Fisch.) O.E. Schulz, Northern Flixweed, 147. Amphi-Beringian.

Draba alpina L., Alpine Whitlow-Grass, 33. Circumpolar.

D. fladnizensis Wulfen, Austrian Whitlow-Grass, 108. Circumpolar. Note that specimen completely lacked hairs.

D. glabella Pursh, Smooth Whitlow-Grass, 54; 100. Circumpolar.

D. lactea Adams, Milky Whitlow-Grass, 185. Circumpolar.

D. nivalis Liljebl,. Snow Whitlow-Grass, 17; 42; 102. Circumpolar.

Eutrema edwardsii R. Br., Edward's Eutrema 22; 34; 45; 99. Circumpolar.

SAXIFRAGACEAE

Parnassia kotzebuei Cham. & Schlect., Small Grass-of-Parnassus, 225. North American Endemic.

P. palustris L. var. *neogaea* Fern., Northern Grass-of-Parnassus, 219. North American Endemic.

Saxifraga aizoides L., Yellow Mountain Saxifrage, 191. Amphi-Atlantic.

S. caespitosa L. ssp. *caespitosa* Engl. & Irmsch., Tufted Saxifrage, 195. Amphi-Atlantic.

S. caespitosa L. ssp. *exaratoides* (Simm.) Engl. & Irmsch., Tufted Saxifrage, 194; 203. North American Endemic.

S. cernua L., Nodding Saxifrage, 127. Circumpolar.

S. hirculus L. var. *propinqua* (R. Br.) Simm., Yellow Marsh Saxifrage, 137. Circumpolar.

S. oppositifolia L., Purple Saxifrage, 7; 26. Circumpolar.

S. rivularis L., Brook Saxifrage, 193. Circumpolar.

S. tenuis (Wahlenb.) H. Sm., Slender Arctic Saxifrage, 47; 57. Amphi-Atlantic.

S. tricuspidata Rottb., Three-toothed Saxifrage, 82. North American Endemic.

ROSACEAE

Dryas integrifolia M. Vahl, Entire-leaved White Mountain-Avens, 29; 38. North American Endemic.

Potentilla egedii Wormskj., Northern Silverweed, 169. Circumpolar.

P. hyparctica Malte var. *elatior* (Abrom.) Fern., Arctic Cinquefoil, 15; 28; 107. Circumpolar.

P. palustris (L.) Scop., Marsh Cinquefoil, 216. Circumpolar.

Rubus chamaemorus L., Cloudberry, 96. Circumpolar.

LEGUMINOSAE

Astragalus alpinus L., Alpine Milk-vetch, 59. Circumpolar.

A. eucosmus Robins., Elegant Milk-vetch, 171. North American Endemic.

Hedysarum alpinum L. var. *americanum* Michx., Alpine Hedysarum, 116. North American Endemic.

H. mackenzii Richards., Northern Hedysarum, 196; 228. North American Endemic.

Oxytropis bellii (Britt.) Palibine, Bell's Arctic Locoweed, 21. North American Endemic.
O. hudsonica (Greene) Fern., Hudson Bay Locoweed, 161. North American Endemic.
O. maydelliana Trautv., Maydell Locoweed, 60. North American Endemic.

EMPETRACEAE
Empetrum nigrum L. ssp. *hermaphroditum* (Lge.) Bocher, Crowberry, 73. Circumpolar.

ONAGRACEAE
Epilobium latifolium L., Broad-leaved Willowherb, 95; 134. Circumpolar.
E. palustre L., Marsh Willowherb, 224. Circumpolar.

HALORAGACEAE
Hippuris vulgaris L., Mare's-Tail, 5; 114. Circumpolar.
Myriophyllum exalbescens Fern., Northern Spiked Water-Milfoil, 182. North American Endemic.

PYROLACEAE
Pyrola grandiflora Radius, Large-flowered Wintergreen, 152. Circumpolar.

ERICACEAE
Andromeda polifolia L., Bog-Rosemary, 97. Circumpolar.
Arctostaphylos alpina (L.) Spreng., Alpine Bearberry, 30. Circumpolar.
Cassiope tetragona (L.) D. Don ssp. *tetragona*, Arctic White Heather, 50. Circumpolar.
Ledum decumbens (Ait.) Lodd., Narrow-leaved Labrador-tea, 79. Circumpolar.
Loiseleuria procumbens (L.) Desv., Alpine Azalea, 76. Circumpolar.
Phyllodoce caerulea (L.) Bab., Purple Mountain-Healther, 144. Circumpolar.
Rhododendron lapponicum (L.) Wahlenb, Lapland Rose-bay, 19. Circumpolar.
Vaccinium uliginosum L., Bog Bilberry, 72. Circumpolar.
V. vitis-idaea L. var. *minus* Lodd., Mountain Cranberry, 117. Circumpolar.

DIAPENSIACEAE
Diapensia lapponica L., Northern Diapensia, 61. Amphi-Atlantic.

PRIMULACEAE
Androsace septentrionalis L., Northern Pygmy-flower, 63. Circumpolar.
Primula egaliksensis Wormsk., Greenland Primrose, 113. North American Endemic.
P. stricta Hornem., Erect Primrose, 112. Amphi-Atlantic.

PLUMBAGINACEAE
Armeria maritima (Mill.) ssp. *labradorica* (Wallr.) Hult., Labrador Sea-thrift, 83; 183. Amphi-Atlantic.

BORAGINACEAE
Mertensia maritima (L.) S.F. Gray, Sea Lungwort, 226. Amphi-Atlantic.

SCROPHULARIACEAE
Castilleja raupii Pennell, Purple Paintbrush, 153. North American Endemic.
Pedicularis capitata Adams, Large-flowered Lousewort, 101. Circumpolar.
P. flammea L., Flame-colored Lousewort, 105. Amphi-Atlantic.
P. labradorica Wirsing, Labrador Lousewort, 145. Circumpolar.
P. lanata Cham. & Schlecht., Woolly Lousewort, 25. North American Endemic.
P. lapponica L., Lapland Lousewort, 104. Circumpolar.
P. sudetica Willd., Purple Rattle, 128. Circumpolar.

CAMPANULACEAE
Campanula uniflora L., Alpine Bluebell, 106. Circumpolar.

COMPOSITAE
Antennaria canescens (Lge.) Malte, Alpine Pussytoes, 110. North American Endemic.
Artemesia borealis Pall., Northern Wormwood, 78; 138. Circumpolar.
Chrysanthemum arcticum L., Arctic Daisy, 214. Circumpolar.
Erigeron eriocephalus J. Vahl, One-flowered Fleabane, 139. Circumpolar.
E. humilus Grah., Arctic Fleabane, 200. Circumpolar.
Matricaria ambigua (Ledeb.) Kryl., Sea-shore Chamomile, 75. Circumpolar.
Senecio congestus (R. Br.) DC., Marsh Ragwort, 155. Circumpolar.
Taraxacum lacerum Greene, Incised Dandelion, 93; 166; 202. North American Endemic.

Discussion

The majority of taxa collected (110 of 165) were of circumpolar distribution, while 33 taxa were North American endemics, 15 taxa were amphi-Atlantic and seven had an amphi-Beringian affinity.

Due to the paucity of published data on the Rankin Inlet area, it is not surprising that five of the vascular plant species listed represent either new records or significant range extensions in the District of Keewatin (Cody 1991, personal communication). *Braya purpurescens* represents a new species record for the continental part of the District of Keewatin. This crucifer is typically found in the High Arctic although there are records for this species in west-central Quebec. Another member of the mustard family, *Descurainia sophioides*, was also found for the first time in the District of Keewatin, with this record bridging a gap between Churchill and the western Arctic. The species, *Saxifraga tenuis* and

Astragalus eucosmus, also represent new records for continental Keewatin. The first Keewatin specimen of Semaphore Grass, *Pleuropogon sabinii*, was found in 1984 near Wager Bay (Cody et al. 1989), with the present Rankin Inlet record representing the second and most southern documented record for this species in the District of Keewatin.

Acknowlegments

The author is grateful to J. H. Hudson for verifying the author's identifications and reviewing the manuscript. Thanks are also extended to W. J. Cody for providing information on current known ranges of several species of Arctic plants. Assistance with some identifications and current taxonomic usages by V. L. Harms and D. F. Brunton are also acknowledged. The author wishes to thank T. Duncan and the Northern Scientific Training Program for the opportunity to work in the arctic. Logistical support was provided by the Government of the Northwest Territories and is greatly appreciated.

Literature Cited

Brunton, D. F. 1981. Taxonomy and status of *Silene uralensis* subsp. *ogilviensis* comb. nov. (Caryophyllaceae) in Yukon Territory, Canada. Canadian Journal of Botany 59(7): 1361–1362.

Cody, W. J., G. W. Scotter, and **S. C. Zoltai.** 1989. Vascular plant flora of the Wager Bay Region, District of Keewatin, Northwest Territories. Canadian Field-Naturalist 103(4): 551–559.

Macoun, James M. 1911. Flora and Fauna of West Coast of Hudson Bay. Geological Survey Canada. Summary Report 1909–10. Pages 281–283.

Porsild, A. E., and **W. J. Cody.** 1980. Vascular Plants of the Continental Northwest Territories, Canada. National Museum of Natural Sciences, Ottawa. 667 pages.

Rowe, J. S., G. R. Cochrane, and **D. W. Anderson.** 1977. The Tundra Landscape near Rankin Inlet, N.W.T. Musk-Ox 20: 66–82.

Savile, D. B. O., and **J. A. Calder.** 1952. Notes on the Flora of Chesterfield Inlet, Keewatin District, N.W.T. Canadian Field-Naturalist 66: 103–107.

Received 21 November 1991
Accepted 1 April 1992

Re-examination of a Water Birch, *Betula occidentalis,* Outlier of the Northwestern Hudson Bay Lowlands

PETER A. SCOTT[1], RICHARD J. STANIFORTH[2] and DAVID C. F. FAYLE[3]

[1]Department of Zoology, University of Toronto, Toronto, Ontario M5S 1A1
[2]Department of Biology, University of Winnipeg, Winnipeg, Manitoba R3B 2E9
[3]Faculty of Forestry, University of Toronto, Toronto, Ontario M5S 3B3

Scott, Peter A., Richard J. Staniforth, and David C. F. Fayle. 1992. Re-examination of a Water Birch, *Betula occidentalis*, outlier of the northwestern Hudson Bay Lowlands. Canadian Field-Naturalist 106(3): 348–351.

A specimen of Water Birch (*Betula occidentalis* Hook.) was found in the north-western Hudson Bay Lowlands in September 1989. A tree in the same location was found by Schofield in 1956 and an extensive ground search confirmed that this is the only specimen in the region. Site pH investigations revealed that this tree was situated on an erratic patch of acidic sand, more typical of Canadian Shield locations where this species is commonly found. Growth and reproductive behaviour was monitored between 1989 and 1991, and compared to the earlier report. Seed production occurred in 1989, but not since. The tree height apparently increased from 4.4 to 5.0 m over 35 years. A dead secondary stem was sampled and dated as establishing prior to 1891, during the Little Ice Age. Radial growth appeared to be slow, insensitive to summer temperatures, but possibly sensitive to drought stress. It is estimated that the tree may be as much as 200 years old.

Key Words: Water Birch, *Betula occidentalis*, NW Hudson Bay Lowlands, outliers, Little Ice Age.

The Water Birch (*Betula occidentalis* Hook.) is a low, multi-stemmed tree of dry slopes, woods, shores and stream banks (Scoggan 1957; Hosie 1973; Porsild and Cody 1980) and is widespread on the prairies (Looman and Best 1979). Extending northward through the boreal forest and into the subarctic (Ritchie 1962; Porsild and Cody 1980), Scoggan (1957) reported this species as far north as Nueltin Lake (59°48'N) in Manitoba. In the northern part of its range, *Betula occidentalis* is characteristic of the more acidic, Canadian Shield sites (Ritchie 1962). It is apparently absent from the calcareous plains of the Hudson Bay Lowlands (Hosie 1973; Porsild and Cody 1980) and no mention is made of the species in most floristic and vegetation studies of that region (e.g., Ritchie 1956, 1960; Zoltai 1973; Sims et al. 1987).

An exception to this was the discovery and collection from a single specimen (described as "*B. minor*" and annotated as *B. occidentalis* by Lepage in 1975) in 1956 by W. B. Schofield and H. A. Crum (S & C below)(Schofield 1959, p. 126):

> "Spreading shrub to 11 feet, with D. B. H. of 4 inches, in dry birch-willow scrub of gravel ridge, Twin Lakes Hill, about 20 miles e. of Churchill (S & C, 7117). Only one shrub was seen, suggesting that this is near the northeastern extreme of its range. The plant was heavy with fruit, but no reproduction was observed from previous years."

Scoggan (1959) cited this record in his local flora of Churchill although subsequent researchers (e.g., Ritchie 1962; Johnson 1987; Porsild and Cody 1980) did not acknowledge this tree.

We report the re-discovery and re-examination of what is apparently the only specimen of *B. occidentalis* that has been found in the northwest Hudson Bay Lowlands and beyond the continuous forest (Ritchie 1962).

Methods

During field studies near Churchill, Manitoba, in September 1989, one of us (Scott) found an unfamiliar birch species growing on Twin Lakes Hill (58°37'N, 93°48'W) in the same location and site reported by Schofield (1959). Measurements were taken of the tree, a specimen collected for later identification (UWPG: *Staniforth and Scott 89–96*, Figure 1), the site characteristics noted, and the immediate vicinity searched for other specimens.

A cross-sectional disk was sawn at approximately 20 cm height above the ground from an 8.5 cm diameter dead stem within the basal clump. The disk was sanded and the ring widths of four radii (SE, SW, E, and NW) were measured using the Tree Ring Increment Measuring system (Fayle and MacIver 1986). The stem cross-section was slightly eccentric with scattered pockets of decay present. Up to 5 mm of decayed wood around much of the circumference resulted in only one radius (SE) being measured completely to the outside. The outer 7, 9, and 11 rings could not be measured on the other radii respectively.

Narrow marker rings were determined using ring widths from similar-aged White Spruce (*Picea glauca* (Moench) Voss) growing nearby (Scott et al. 1988). Also using growth rings from a nearby White Spruce, autocorrelations were calculated for ± 20

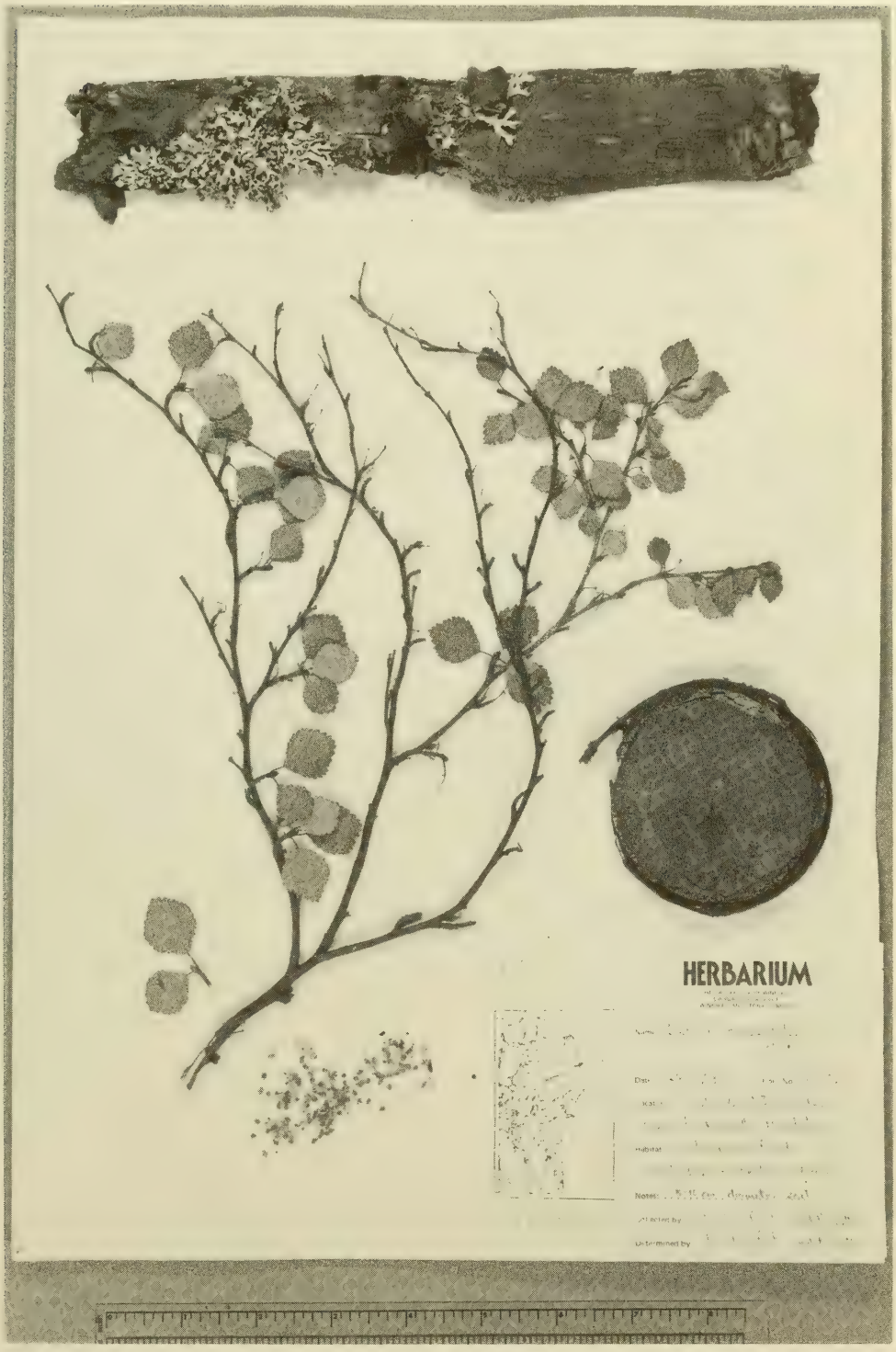


FIGURE 1. The herbarium specimen of *Betula occidentalis* (UWPG: *Staniforth and Scott 89–96*) collected from Twin Lakes, Manitoba, during 1989.

years from 1975. The average ring width series was then cross-dated using marker rings and multivariate autocorrelations (Fritts 1976).

During 1991, the soil profile was examined and the pH of the parent material was measured.

Results

Based on various identification keys (Dugle 1966; Scoggan 1978; Looman and Best 1979) the tree was determined to be *B. occidentalis* (Figure 1) and an extensive ground search confirmed that this was the only specimen in the region. In 1989, the tree consisted of a clump of six living stems 8–10 cm in diameter at the base, an apparent main stem of about 15 cm in diameter, and several dead stems. [We did not re-measure the DBH because we could not determine which stem was measured from the previous study (Schofield 1959).] Maximum height was 4.98 m. The bark was reddish brown, smooth, shiny and not exfoliating, except where damaged. The leaves were 2.4 cm in length, more or less doubly serrate with 13–15 teeth per margin. A few female catkins remained on the tree and they shattered on touch. Seeds were firm and possessed wings as wide as the body of the seed. (The tree did not produce seed in 1990 or 1991.)

Twin Lakes Hill is a kame containing two main kettle lakes (Dredge and Nixon 1986). The birch tree was at the top of a sandy slope approximately 50 m from the shore of a smaller lake within the original East Twin Lake basin. The vegetation of the area is described as White Spruce open forest (Ritchie 1960, 1962) composed mostly of White Spruce-lichen woodland. The ground is covered mainly with *Cladina stellaris* and *C. rangiferina* and there is an intermittent shrub layer of *Ledum groenlandicum*, *Betula glandulosa*, and *Salix* spp. (predominantly *S. planifolia*). The cryosol is composed of 2–6 cm of fibric peat over unsorted gravel and sand. The pH of the parent material in the immediate area ranges from 4.4 to 4.8.

The stem cross-section contained 85 rings, the last identifiable ring was either 1968 or 1975. (The two dates reflect the use of two methods which lead to somewhat different results.) In any case, this secondary stem therefore began its development prior to 1891 (Figure 2).

Discussion

Typical pH of the glacial tills and marine sands underlying the region (Dredge and Nixon 1986) ranges from 7.8 to 8.8. Thus, the acidic sand found around the birch tree is unusual for this region (Scott, unpublished); another small pocket of acidic sand is found nearby on this kame. These sands, associated with the original kame formation, were probably transported from Canadian Shield locations in the Keewatin and have remained somewhat intact during the post-glacial marine submergence (see Ritchie 1962; Dredge and Nixon 1986).

The emergent kame is one of the few elevated sites in this section of the Hudson Bay Lowlands and has been subject to frequent fires (Scott et al. 1988). The post-fire succession has led to the current, lush

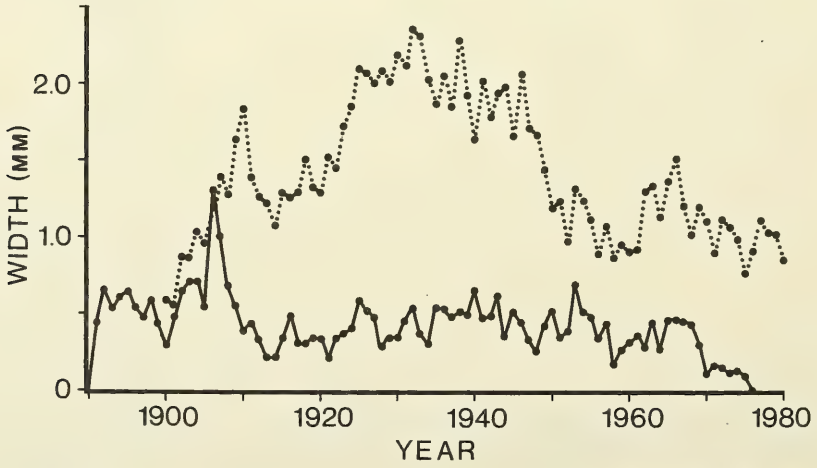


FIGURE 2. Comparison of the average ring widths from four radii of the sampled birch stem (solid line) and the specific volume increment of a nearby White Spruce stem (dotted line). The specific volume increment is equivalent to the average ring width of the annual growth layer.

White Spruce-lichen woodland (Ritchie 1962) as well as other unusual Boreal-type communities such as poplar (*Populus balsamifera*) forests (Ritchie 1956). Frequent disturbance by fire at Twin Lakes will open up areas for colonization and thus, be more receptive to random seed dispersal than the less dynamic boglands that surround the kame.

Between 1956 and 1989, the main stem appeared to have increased in diameter from approximately 10 cm DBH to slightly less than the current basal diameter of 15 cm and increased in height from 4.4 to 5.0 m. The tree ring analysis of the dead secondary stem indicated that the birch tree clump is currently at least 100 years old. The presence of the larger stem and the apparent increase in diameter since the Schofield (1959) report indicates that the tree could be closer to 200 years in total age.

Typical of the multi-stemmed growth habit, annual differences in wood production are distributed over several stems. Consequently, the growth trend exhibited by a single stem is fairly constant (Figure 2). Unlike the White Spruce, the birch ring widths do not show as strong a response to the early 20th century warming or the subsequent cooling that was prominent in this area (Scott et al. 1988). The insensitivity to climate processes suggests that the tree is probably not growing under restrictive, low summer temperatures. In fact the establishment of this tree dates to a period within the Little Ice Age (see Scott et al. 1988). The decline and subsequent death of the sampled stem begins during the 1960s and corresponds to a four-year period (1964-1968) of extreme summer drought (Churchill Weather Office, Churchill, Manitoba) accentuated by the fact that the tree is growing on a very dry site.

In summary, the high disturbance frequency associated with fires makes the Twin Lakes Hill potentially a good site for colonization by new species. During the Little Ice Age, the Water Birch outlier was established at Twin Lakes on an erratic patch of acidic sand atypical of the calcareous Hudson Bay Lowlands. The individual has grown and developed over the last century or more developing seed while not reproducing successfully. Changes in the summer temperature regime have had little influence although there is some indication that the dry site may be stressful for the tree.

Acknowledgments

We wish to thank I. M. Brodo for sending us the initial report by Schofield and two anonymous reviewers for helpful comments on the manuscript. Temperature and precipitation data were provided by the Churchill Weather Office, Churchill, Manitoba. Funding was provided through N.S.E.R.C. and N.S.T.P. to Scott.

References Cited

Dredge, L. A., and **F. M. Nixon.** 1986. Surficial Geology, Northeastern Manitoba. Geological Survey of Canada, Map 1617A.

Dugle, J. R. 1966. A taxonomic study of western Canadian species in the genus *Betula*. Canadian Journal of Botany 44: 929–1007.

Fayle, D. C. F., and **D. C. MacIver.** 1986. Growth layer analysis as a method of examining tree growth and development responses. Pages 40–48 *in* Environmental Influences on Tree and Stand Increment. *Edited by* D. S. Solomon, and T. B. Brann. Maine Agricultural Experimental Station Miscellaneous Publication, University of Maine.

Fritts, H. C. 1976. Tree rings and climate. Academic Press, London.

Hosie, R. C. 1973. Native Trees of Canada. Canadian Forestry Service, Ottawa.

Johnson, K. L. 1987. Wildflowers of Churchill and the Hudson Bay Region. Manitoba Museum of Man and Nature, Winnipeg.

Looman, J., and **K. F. Best.** 1979. Budd's Flora of the Canadian Prairie Provinces. Agriculture Canada Publication 1662, Ottawa.

Porsild, A. E., and **W. J. Cody.** 1980. Vascular Plants of the Continental Northwest Territories, Canada. National Museums of Canada, Ottawa.

Ritchie, J. C. 1956. The native plants of Churchill, Manitoba, Canada. Canadian Journal of Botany 34: 269–320.

Ritchie, J. C. 1960. The vegetation of northern Manitoba. V. Establishing the major zonation. Arctic 13: 210–229.

Ritchie, J. C. 1962. A geobotanical survey of northern Manitoba. Arctic Institute of North America Technical Paper Number 9. 46 pages.

Schofield, W. B. 1959. The salt marsh vegetation of Churchill, Manitoba and its phytogeographic implications. National Museum of Canada Bulletin 160.

Scoggan, H. J. 1957. Flora of Manitoba. National Museum of Canada Bulletin 140.

Scoggan, H. J. 1959. The Native Flora of Churchill, Manitoba. National Museum of Canada, Ottawa.

Scoggan, H. J. 1978. Flora of Canada. National Museums of Canada Publications in Botany 7.

Scott, P. A., D. C. F. Fayle, C. V. Bentley, and **R. I. C. Hansell.** 1988. Large scale changes in atmospheric circulation interpreted from patterns of tree growth at Churchill, Manitoba, Canada. Arctic and Alpine Research 20: 199–211.

Sims, R. A., G. M. Wickware, and **D. W. Cowell.** 1987. A study of coastal vegetation at a site on Hudson Bay near Winisk, Ontario. Canadian Field-Naturalist 101: 335–345.

Zoltai, S. C. 1973. Vegetation, surficial deposits and permafrost relationships in the Hudson Bay Lowlands. Pages 17–34 *in* Proceedings of the Symposium on the Physical Environment of the Hudson Bay Lowland, March 1973, University of Guelph, Guelph, Ontario.

Received 20 December 1991
Accepted 4 March 1992

Notes on Short-eared Owl, *Asio flammeus,* Nest Sites, Reproduction, and Territory Sizes in Coastal Massachusetts

Denver W. Holt

Owl Research Institute, P.O. Box 8335, Missoula, Montana 59807

Holt, Denver W. 1992. Notes on Short-eared Owl, *Asio flammeus,* nest sites, reproduction, and territory sizes in coastal Massachusetts. Canadian Field-Naturalist 106(3): 352–356.

Short-eared Owls (*Asio flammeus*) were studied from 1982 to 1987 on Monomoy National Wildlife Refuge (NWR) (828 ha), Cape Cod, Chatham, Massachusetts. Monomoy NWR are barrier beach islands. Male Short-eared Owls sky dance to attract prospective females. The owls nested in secondary herbaceous grass/sand dune vegetation. Nest sites were dominated by beach grass (*Ammophila breviligulata*), 35.5 to 53.3 cm in height (x = 45.1, SD = 5.0; N = 9). Mean clutch size was 6.2 (SD = 2.2, range 4 to 10; N = 9), and mean hatching success was 4.7 (SD = 2.4, range 0 to 9; N = 9). Mean fledging success for 22 nesting attempts was 3.2 (SD = 1.6, range 1 to 7). Sibling cannibalism occurred at two nests. Territory sizes ranged from 48 to 126 ha, x = 64, SD = 23 (N = 10).

Key Words: Short-eared Owl (*Asio flammeus*), clutch size, hatching and fledging success, mortality, nest sites, territory sizes.

The Short-eared Owl (*Asio flammeus*) is common throughout much of its breeding range and one of the most widely distributed owls in the world (Burton 1973). In northeastern United States, Short-eared Owls are uncommon and exist on the southeastern fringe of their North American breeding range. In 1985, the number of breeding pairs in northeastern United States was estimated at less than 55 pairs (Holt 1986a). Of these, 20 to 25 breeding pairs were located in three coastal counties in Massachusetts (Holt 1986b).

Habitat loss through reforestation of farmlands, fragmentation and development of coastal grasslands, and perhaps vegetation succession, contributed to the decline of Short-eared Owls in Massachusetts. Habitat loss through development is probably the single most important factor causing their decline (Holt 1986a).

My objectives were: (1) describe the nesting cycle and reproductive success, (2) estimate territory sizes and owl populations, and (3) record interesting observations.

Study Area

Monomoy National Wildlife Refuge (NWR), is located at the "elbow" of Cape Cod, Barnstable County, Chatham, Massachusetts (Figure 1). Monomoy NWR encompassed three islands. This study was conducted on North and South Islands. The refuge is part of a barrier beach ecosystem which evolved from eroding glacial deposits from outer Cape Cod (Giese 1981).

The islands extend linearly 10.7 km south into the Atlantic Ocean. North Island (126 ha) was 2.7 km long and 0.5 km at its widest point. Varied upland habitat covered 64 ha (Norton et al. 1984), and 62 ha were estuarine habitats (Cowardin et al. 1979). South Island (700 ha) was 8.0 km long and 2.4 km at its widest point. Upland habitats covered 604 ha, and 48 ha of palustrine, 37 ha of estuarine and 11 ha of lacustrine habitats covered the remainder. South island contained a number of natural and man-made fresh water ponds from 1 to 11 ha. The freshwater ponds and marshes of South Island maintained the greatest floral (Lortie et al. 1991), and faunal diversity (Holt et al. 1985; Holt et al. 1987).

Methods

I studied Short-eared Owls from 1982-1987, although intensity varied among years. Field seasons covered March through September with few visits in fall and winter. I located owls daily (weather permitting) in March or April by flushing them from day roosts, and observations of foraging bouts and courtship flights. I distinguished sexes by their color, males being very light and females darker, their courtship behavior (see Holt 1985), and presence of incubation patches on females. I located nests by searching the ground beneath the area where male courtship sky-dancing displays (see Holt 1985) and nest defense and distraction displays occurred.

I described and habitat typed vegetation at nests. I measured the height of vegetation immediately surrounding the nest by placing a meter stick in the nest center and eyeballing from the four cardinal directions. Because vegetation at all nests was relatively homogeneous in height, only one value per nest was recorded. I also identified vegetation within a one meter circle around the nest. Habitat types followed Norton et al. (1984) for upland habitats

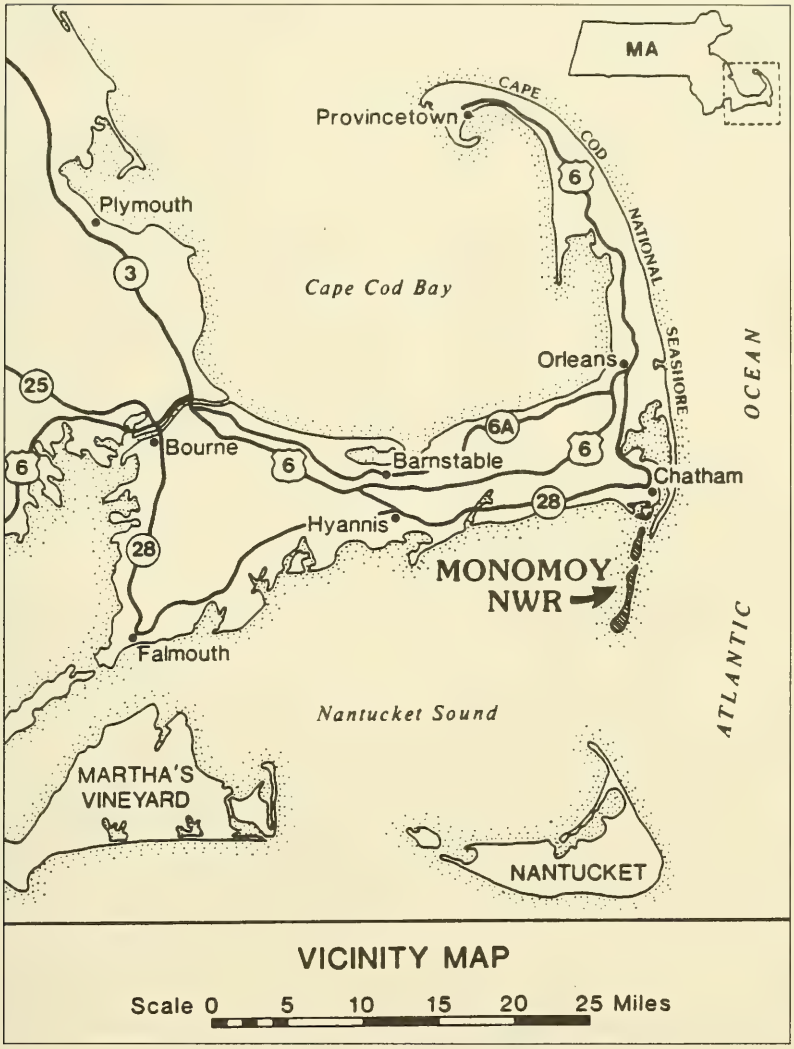


FIGURE 1. Cape Cod and Monomoy Islands.

and Cowardin et al. (1979) for wetland regimes. Plant names followed that of Lortie et al. (1991).

Clutch size and hatching success per nest were determined for nests whose complete history was known. Fledging success was calculated from all nesting attempts. This division was established because some nests were located after all eggs had hatched. When nestlings dispersed from a nest, I located them in late afternoon or evening by their food begging calls. I returned to these areas until I could determine how many nestlings fledged from each nest.

I estimated territory sizes around nest sites, by using roosting sites, courtship flights, intraspecific territorial chases and skirmishes, and foraging bouts. I used 25 observations of some flight behavior per territory to estimate the sizes. I plotted these observations on USGS topographical maps (scale 1:25 000). Minimum convex polygons were draw by connecting the outermost points. I then digitized the polygons to estimate territory sizes. I used a Numonics Corp Electronic Graphic Calculator and Digitablet (Model 2400) for these estimates.

Results

I located 22 nests during the study. I was unable to determine which sex selected the nest site. Males appeared to select the area, as indicated by their courtship sky-dancing flights. Nest sites were selected when the previous year's residual vegetation was

dead and matted down from wind and moisture. Vegetation height at 9 nest sites ranged from 35.5 to 53.3 cm (x = 45.1, SD = 5.0). Greater than 90% vegetation cover at each nest was matted down residual beach grass (*Ammophila breviligulata*). Vegetative classification at all nests (N = 22) was herbaceous secondary beach grass/sand dune complexes (Norton et al. 1984).

Nests were normally a bowl of dried grass and few downy owl feathers — likely from the incubating female. Or, a slight circular depression created by the females incubating and brooding posture. In one nest, the eggs were laid on bare ground with no nest material or circular depression. I never observed nest construction. Three of four females that flushed from nest scrapes before egg laying moved a short distance to new locations and nested. Similar unoccupied scrapes were near active nests.

I seldom visited nests during incubation in order to minimize disturbances. All clutches hatched asynchronously. Female owls did all incubating and brooding, while males provided them with food. For 9 nests where complete history was known, mean clutch size was 6.2, SD = 2.2, range 4 to 10, mean hatching success 4.7, SD = 2.4, range 0 to 9, and mean fledging success 3.2, SD = 2.2, range 1 to 7. Mean fledgling success for the additional 13 nests whose complete histories were unknown, was also 3.2, SD = 1.6, range 1 to 7. Young owls fledged approximately four to five weeks after hatching.

I recorded 13 cases of mortality of which 11 were identified to cause. Five were sibling cannibalism, 3 were shot, 1 adult was killed by a Bald Eagle (*Haliaeetus leucocephalus*), 1 pre-fledged disperser was killed by a Herring Gull (*Larus argentatus*), and 1 pre-fledged disperser drowned in a high tide.

In the two nests where sibling cannibalism occurred, two and three nestlings were eaten, respectively. Dead uneaten voles were present in these nests; however, the voles may have been delivered after the cannibalism. Competition for the voles could also have resulted in death and consumption of nest mates. Or, the nestlings may have died naturally and were then cannibalized. I never observed the killing and eating of one sibling by another.

Ten territory sizes were estimated; three from North Island and seven from South Island. Mean territory size was 64.7 ha, SD = 22.8, range 48 to 126 ha. If the 126 ha territory is removed, however, then territory sizes were more uniform (x = 58.0, SD = 8.1, range 48 to 68). I removed the 126 ha North Island territory because almost half the habitat was estuarine. Owls foraging in the upland habitat always crossed the estuarine areas, thus utilizing the entire island. Prey species, however, seldom occurred there. In 1985, 1986, and 1987, only one pair of Short-eared Owls nested on North Island. I did not determine territory size for those years, however, I believed this island could only maintain one pair of nesting owls, except on rare occasion. The largest concentration of owls (3-4 pairs) occurred near the freshwater ponds on South Island. Owls consistently nested in this area, unfortunately, individual owls were not known.

One banded adult Short-eared Owl was recovered (# 576-90091) on North Island on 31 May 1986. Cause of death could not be determined. The owl appeared to have been dead several days, and many feathers were missing from the carcass. I believed this owl to be the female previously incubating a nest 3 meters away from the carcass. Brood patch or gonadal determination was not possible. The owl was banded by Norman Smith and I on 13 May 1984, on South Island, 4.8 km from the recovery site. It was the second nestling to hatch of a ten egg clutch, was ten days old and weighed 215 grams when banded. It lived about 740 days.

Discussion

Male Short-eared Owls in this study appeared to select the nesting area as indicated by their sky-dancing displays. Sky-dancing courtship behavior is a unique aspect of Short-eared Owl breeding biology. It has been best described by Du Bois (1924) and Holt (1985). I suspected females selected the nest site. I could not locate any literature stating which sex selects the actual nest site.

Pitelka et al. (1955a) reported female Short-eared Owls to occupy a nest in incubating position before the first egg was laid. Clark (1975) flushed female Short-eared Owls from freshly made scrapes. My observations indicated that females may investigate several potential nest sites, scraping out bowls, lining them with grasses and assuming an incubating posture. Disturbance at that time may affect the site chosen.

Nest characteristics in this study were similar to those reported elsewhere (Forbush 1927; Bent 1938, Clark 1975; Mikkola 1983; Cramp 1985). Nest locations for Short-eared Owls have been reported in moist habitats; e.g., moorlands, salt marshes, tundra (Urner 1923; 1925; Pitelka et al. 1955b; Burton 1973; AOU 1983; Mikkola 1983) and upland habitats (Trann 1974; Clark 1975; Duebbert and Lokemoen 1977; this study). The congeneric Marsh Owl (*Asio capensis*), however, seems to prefer bogs or marshes for its nesting requirements (Smith and Killick-Kendrick 1964).

Clutch size for North American Short-eared Owls has been summarized by Murray (1976). He examined geographic variation by region and latitude. From 186 clutches analyzed, Murray reported mean clutch size of 5.6, range 1 to 11. When delineated to region and latitude, this study falls in Murray's

region 1, latitude 40 to 44 north. He reported mean clutch size for this region at 3, range 1 to 8 (N = 3). This is less than half of that reported in this study. In coastal New Jersey, Urner (1923) reported one clutch of 6, and Urner (1925) reported a mean of 6.8 (N = 4). Murray's overall mean of 5.6 and this study's mean of 6.2 were similar. His regional and latitudinal sample sizes were too small for broad generalizations or comparisons. Duebbert and Lokemoen (1977) reported mean clutch size of 7.0, range 4 to 9 (N = 13) from North and South Dakota. Mean clutch size for 121 European nests was 7.3, range 2 to 13 (Mikkola 1983).

Mean hatching success per nest has been reported. Kitchin (1919) reported 3.5 (N = 2), Urner (1923, 1925) reported 0 (N = 1), and 4.8 (N = 4), Clark (1975) reported 7.5 (N = 4), and Holt and Melvin (1986) reported 3.4 (N = 7). Duebbert and Lokemoen (1977) reported 100% hatching success for 14 nests, but did not report breakdown per nest. In Europe, Cramp (1985) reported 36% (44/121) hatching success from 17 nests. My results fall within these ranges.

Literature reporting fledging success is scarce. Clark (1975) reported 4.0 owls per nest (N = 4), Linner (1980) reported 1.8 per nest (N = 4), and Holt and Melvin (1986) reported 2.1 per nest (N = 7). Data from this study is similar, however, more fledging success data is needed. The mean number fledged per nest seem low. Given the large clutches Short-eared Owls are capable of laying, could this be the cost of ground nesting? Clark (1975) reported Short-eared Owl young to fledge when approximately 27 days old, in Manitoba. Urner (1923) estimated fledging at approximately 31 to 36 days in New Jersey. My data are in agreement.

Sibling cannibalism reported here, has also been reported from species with fluctuating food resources (Ingram 1959). Brood reduction resulting from sibling cannibalism has been reported for other raptor species (Ingram 1959), including Short-eared Owls (Ingram 1962).

A wide range of breeding season territory sizes have been reported for Short-eared Owls. In North America, mean territory sizes reported were: 81.8 ha, range = 23.1 to 121.4, N = 6 (Clark 1975), and 55 ha, range 25 to 75, N = 9 (Holt and Melvin 1986). In Scotland, Lockie (1955) reported a mean of 17.8 ha (N = 7). These territory sizes, however, changed as the season progressed and owls departed because of low prey densities. Consequently, Lockie's territory sizes changed to a mean of 137.2 ha (N = 2). Gronlund and Mikkola (1969) reported a mean of 50 ha, from their study in Finland. Village (1987) reported mean territory sizes at 83 ha, SD = 6.0, range 25 to 242 (N = 51), for Short-eared Owls in Scotland. My results are also in agreement with these previous reports.

The band recovery reported here provided information on natural longevity, and natal dispersal distance. The distance of 4.8 km from the natal nest to the place of mortality fits Greenwood's (1980) definition of natal dispersal. Conclusive proof that the dead owl was also the female previously incubating the nearby nest could not be determined.

Literature Cited

American Ornithologists' Union. 1983. Check-list of North American birds, Sixth edition. American Ornithologists' Union, Washington, D.C.

Bent, A. C. 1938. Life histories of North American birds of prey. Part 2, United States National Museum Bulletin 170.

Burton, J. A. 1973. Owls of the world. E. P. Dutton and Company, New York.

Clark, R. J. 1975. A field study of the Short-eared Owl *Asio flammeus* (Pontoppidan) in North America. Wildlife Monographs 47: 1–67.

Cowardin, L. M., V. Carter, F. C. Golet, and **F. T. LaRoe.** 1979. Classification of wetlands and deep water habitats of the United States. United States Fish and Wildlife Service FWS/OBS-79/31. 103 pages.

Cramp, S. *Editor.* 1985. The birds of the western Palearctic, Volume 4. Oxford University Press, London.

Du Bois, A. D. 1924. A nuptial song flight of the Short-eared Owl. Auk 41: 260–263.

Duebbert, H. F., and **J. T. Lokemoen.** 1977. Upland nesting of American Bitterns, Marsh Hawks and Short-eared Owls. Prairie Naturalist 9: 33–40.

Forbush, E. H. 1927. Birds of Massachusetts and other New England states. Volume 2, Massachusetts Department of Agriculture.

Giese, G. S. 1981. The barrier beaches of Chatham. Bird Observer of Eastern Massachusetts 9: 107–110.

Greenwood, P. J. 1980. Mating systems, philopatry and dispersal in birds and mammals. Animal Behavior 63: 1140–1162.

Gronlund, S., and **H. Mikkola.** 1969. On the ecology of the Short-eared Owl in Lapua Alajoki in 1969. Suomenselan Linnut 4: 68–76.

Holt, D. W. 1985. The Short-eared Owl in Massachusetts. The Cape Naturalist 14: 31–35.

Holt, D. W. 1986a. Status Report: The Short-eared Owl in the Northeast. Eyas 9: 3–5.

Holt, D. W. 1986b. A summary of Short-eared Owl breeding status in Massachusetts. Bird Observer of Eastern Massachusetts 14: 234–237.

Holt, D. W., and **S. M. Melvin.** 1986. Population dynamics, habitat use, and management needs of the Short-eared Owl in Massachusetts. Summary of 1985 research. Massachusetts Division of Fisheries and Wildlife, Natural Heritage Program. 57 pages.

Holt, D. W., J. P. Lortie, and **R. C. Humphrey.** 1985. An inventory of the birds of Monomoy National Wildlife Refuge, Chatham, Massachusetts, 1984. Bird Observer of Eastern Massachusetts 13: 193–195.

Holt, D. W., R. C. Humphrey, and **J. P. Lortie.** 1987. The mammals of Monomoy National Wildlife Refuge. The Cape Naturalist 15: 63–69.

Ingram, C. 1959. The importance of juvenile cannibalism in the breeding biology of certain birds of prey. Auk 76: 218–226.

Ingram, C. 1962. Cannibalism by nestling Short-eared Owls. Auk 79: 715.

Kitchin, E. A. 1919. Nesting of the Short-eared Owl in western Washington. Condor 21: 21–25.

Linner, S. C. 1980. Resource partitioning in breeding populations of Marsh Hawks and Short-eared Owls. Unpublished MS. thesis, Utah State University, Ogden, 66 pages.

Lockie, J. D. 1955. The breeding habits and food of Short-eared Owls after a vole plague. Bird Study 2: 53–69.

Lortie, J. P., B. A. Sorrie, and **D. W. Holt.** 1991. Flora of the Monomoy Islands, Chatham, Massachusetts. Rhodora 93: 361–389.

Mikkola, H. 1983. Owls of Europe. Buteo Books, Vermillion, South Dakota.

Murray, G. A. 1976. Geographic variation in the clutch size of seven owl species. Auk 93: 602–613.

Norton, D. J., J. Organ, and **T. Litwin.** 1984. Habitat classification and cover type mapping for the Long Island National Wildlife Refuge Complex. United States Fish and Wildlife Service Report, Newton Corners, Massachusetts. 20 pages.

Pitelka, F. A., P. Q. Tomich, and **G. W. Treichel.** 1955a. Ecological relations of jaegers and owls as lemming predators near Barrow, Alaska. Ecological Monograph 25: 85–117.

Pitelka, F. A., P. Q. Tomich, and **G. W. Treichel.** 1955b. Breeding behavior of jaegers and owls near Barrow, Alaska. Condor 57: 3–18.

Smith, V. W., and **R. Killick-Kendrick.** 1964. Notes on the breeding of the Marsh Owl (*Asio capensis*) in northern Nigeria. Ibis 106: 119–123.

Trann, K. 1974. Short-eared Owls near Edmonton, 1970-1973. Blue Jay 32: 148–153.

Urner, C. A. 1923. Notes on the Short-eared Owl. Auk 40: 30–36.

Urner, C. A. 1925. Notes on two ground nesting birds of prey. Auk 42: 31–41.

Village, A. 1987. Numbers, territory size and turnover of Short-eared Owls in relation to vole abundance. Ornis Scandinavica 18: 198–204.

Received 30 December 1991
Accepted 16 March 1992

Hunter-harvest of Captive-raised Male White-tailed Deer, *Odocoileus virginianus*, Released in Upper Michigan

JOHN J. OZOGA, ROBERT V. DOEPKER, and RICHARD D. EARLE

Michigan Department of Natural Resources, (J. J. O.) Shingleton, Michigan 49884, (R.V.D.) Norway, Michigan 49870, and (R. D. E.) Houghton Lake Heights, Michigan 48630

Ozoga, John J., Robert V. Doepker, and Richard D. Earle. 1992. Hunter-harvest of captive-raised male White-tailed Deer, *Odocoileus virginianus*, released in Upper Michigan. Canadian Field-Naturalist 106(3): 357–360.

Hunter recovery of tagged animals indicate that captive-raised male White-tailed Deer released in Upper Michigan when < 1 year old and > 3 years old died more frequently, and probably sooner, than expected due to non-hunting related factors. Hunters harvested those released when 1-3 years old sooner than expected, but at a rate comparable to that of wild bucks tagged when > 1 year old. Post-release survival rates of captive-raised deer released in northern environments may be improved by releasing them after snowmelt in spring, but even then a high first year post-release death rate should be anticipated.

Key Words: White-tailed Deer, *Odocoileus virginianus*, captive-raised, hunting, mortality factors.

Wildlife agencies and wildlife rehabilitators frequently release captive-raised White-tailed Deer in the wild. However, such semi-domesticated animals tend to experience abnormally high mortality during the first year post-release, even in seemingly favorable environments (McCall et al. 1988), as do translocated wild deer (Jones and Witham 1990). We know of no investigations designed to determine the fates of captive-raised White-tailed Deer released where they are subjected to prolonged climatic stress and acute malnutrition in winter. In this study, we monitored the hunter-harvest rates of captive-raised and wild male White-tailed Deer released in Upper Michigan, as means of assessing their comparative survivability in a northern environment.

Study Area and Methods

This study was conducted in the vicinity of Shingleton, in Alger County, Michigan (46°34'N, 86°37'W), from 1955-1988. The area (Figure 1) lies in the cold deep snow belt along the south shore of Lake Superior, where malnutrition related losses of deer and predation of weakened animals commonly occur during severe winters (Verme and Ozoga 1971). Wild male deer were live-trapped, ear-tagged and released at the trap site (Ozoga 1969) in the Petrel Grade deeryard (Ozoga 1968; Verme and Johnston 1986). Captive-raised male deer (of known age) were raised in small (15 × 30 m) pens at the Cusino Wildlife Research Station (Verme and Ozoga 1980) and in the 252-ha Cusino enclosure (Ozoga and Verme 1982) and later released in or near the Petrel Grade deeryard. Although nearly equal numbers of female deer were also tagged and released, infrequent hunter harvest of antlerless deer in this area precluded data analysis for both sexes.

Wild deer were captured in box traps January–March, restrained without drugs, ear-tagged, sexed, sometimes weighed, classified as fawns (< 1 year old) or adults (> 1 year old) based on dentition (Severinghaus 1949) and released. A total of 195 (145 fawns, 50 adults) wild male deer was marked and released.

Sixty-five (54 fawns, 11 adults) of 73 pen-raised deer were nursed by their mothers when infants. The remaining eight (all fawns at release age) were orphaned at young age and bottle-fed. All received ad libitum pelletized feed providing 16% crude protein and 3.0 kcal/g of energy (Ullrey et al. 1971). Forty-one of the pen-raised fawns (including all ophans) were released in September or October, whereas 32 (21 fawns, 11 adults) were released in March or April.

The natural diet of 166 of 181 (91.7%) enclosure-raised deer in this study was supplemented year-round with the pelletized ration mentioned above. A complete census of the enclosure herd was obtained annually in March by live-trapping. At that time, the animals were transferred from the live traps to a carrying crate and transported (1-3 km) to a processing area. Each animal was then blood-sampled, measured, weighed, and ear-tagged. Those that survived handling, but were not returned to the enclosure (97 male fawns, 84 adult males) were transported 10–20 km and released.

Recovery locations of tagged animals were determined to the center of the specific square mile, and plotted on a base map to compute the straight-line distance, and direction, from release to kill site. We did not publicize the study, nor did we offer a reward for tag information. Consequently, we probably were not notified of every tagged deer recovered.

Statistical comparison of hunter-harvest data for pen-raised, enclosure-raised, and wild male deer, by age-class, were made by Chi-square analysis. Differences in longevity (i.e., number of days from release to recovery) and distance traveled between tagging and recovery sites were compared using Kruskal-Wallis one-way analysis of variance. Differences were considered significant when $P \leq 0.05$.

Results

Seventy-four of 304 (24.3%) male deer tagged and released as fawns, and 62 of 145 (42.8%) as adults, were recovered (Table 1). Hunters accounted for 120 of 136 recoveries (89.2% and 87.1%, of the fawns and adults, respectively). In addition, 10 were recovered after being killed by automobiles, two were poached, one was killed by domestic dogs, and three died from unknown causes.

Among the deer raised in small pens, those released as fawns were less frequently harvested by hunters than were those released at an older age (8.1% vs. 54.6%, respectively; $\chi^2 = 11.84$, 1 df, $P = 0.001$). The same deer age/hunter-harvest relationship approached significance for enclosure-raised animals (17.5% vs. 31.0%, respectively; $\chi^2 = 3.51$, 1 df, $P = 0.061$), but not for wild ones (30.3% vs. 44.0%, respectively; $\chi^2 = 2.53$, 1 df, $P = 0.111$). Although hunter recovery rates for spring released pen-raised and enclosure-raised fawns were similar (19.1% vs. 17.5%, respectively) only 1 of 41 (2.4%) pen-raised fawns released in autumn (none of 8 orphaned at young age) was known to have been recovered by hunters. Captive-raised (pen and enclosure) adult bucks released at approximately 22 or 34 months of age were significantly ($\chi^2 = 6.92$, 2 df, $P = 0.031$) more prone to recovery (25 of 56 = 44.6% and 11 of 20 = 55.0%, respectively) than were those released at older age (3 of 19 = 15.8%).

Considerable variation occurred in amount of elapsed time (i.e., days) from release to recovery for pen-raised, enclosure-raised and wild male fawns ($H = 9.05$, 2 df, $P = 0.011$) and for adult males ($H = 18.84$, 2 df, $P = 0.001$). Of the captive-raised deer recovered, all 7 pen-raised fawns and most others (4 of 6 = 66.7% pen-raised adults, 16 of 20 = 80.0% enclosure-raised fawns, and 29 of 33 = 87.9% enclosure-raised adults) were recovered within one year of their release. In contrast, a higher percentage of wild deer (22 of 44 = 50.0% fawns, 12 of 23 = 52.2% adults) were recovered in subsequent years.

The distance fawns traveled between release and recovery locations differed according to their rearing history ($H = 7.42$, 2 df, $P = 0.024$); wild fawns, on average, traveled farther (21.7 ± 12.3 (SD) km) than those raised in small pens or the enclosure (13.6 ± 14.7 km and 16.3 ± 8.2 km, respectively). Although wild adult males also exhibited a tendency to travel farther (18.9 ± 16.4 km), as compared to pen- and enclosure-raised adults (7.7 ± 7.2 km and 10.6 ± 10.6 km, respectively), the difference was not significant ($H = 3.74$, 2 df, $P = 0.154$).

Wild deer in our study occupied a fairly remote area of conifer swamp in winter, from which they normally dispersed north- and eastward, in a pattern identical to that reported by Verme (1973: Figure 1), to occupy summer range even further away from major highways and human habitation. However, captive-raised deer were more frequently recovered outside of the normal dispersal corridor (Figure 1), nearer to a major highway (M-28) and somewhat greater human population, south- and westward.

Discussion

The relative importance of mortality factors differ among studies, but capture myopathy, malnutrition, predation, vehicle accidents, and hunting have been

TABLE 1. Recovery rates of pen-and enclosure-raised versus wild male White-tailed Deer released in Upper Michigan (1955–1988).

Release age and source	No. tagged	No. recovered (%)		
		Legal hunter kill	Other	Total
Fawns (< 1 year old)				
Wild	145	44 (30.3)	3 (2.1)	47 (32.4)
Enclosure	97	17 (17.5)	3 (3.1)	20 (20.6)
Pens				
< 6 months*	41	1 (2.4)	1 (2.4)	3 (7.3)
≥ 9 months**	21	4 (19.1)	0 (0.0)	4 (19.1)
Adults (> 1 year old)				
Wild	50	22 (44.0)	1 (2.0)	23 (46.0)
Enclosure	84	26 (31.0)	7 (8.3)	33 (39.3)
Pens	11	6 (54.6)	0 (0.0)	6 (54.6)

*Animals < 6 months old released in September or October.
**Animals ≥ 9 months old released in March or April.

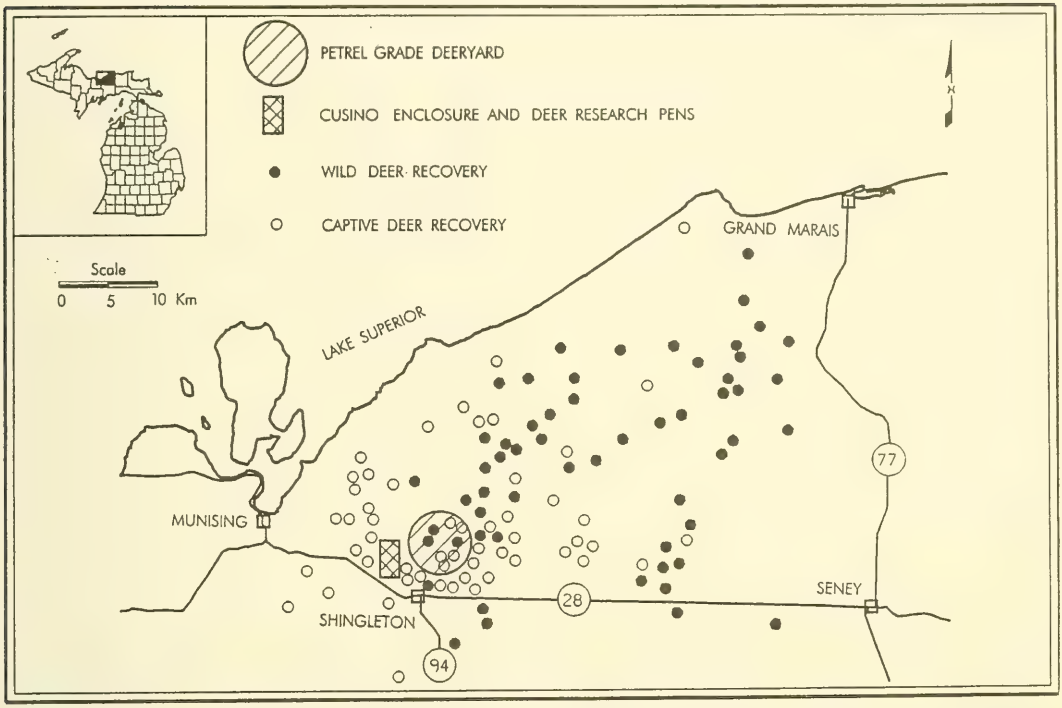


FIGURE 1. Hunter recovery locations of captive-raised and wild male White-tailed Deer released in the Petrel Grade deeryard. Captive deer were raised in the research pens or the 252-ha enclosure located at the Cusino Wildlife Research Station, then released in the Petrel Grade deeryard. Insert shows location of study area in Upper Michigan.

implicated in excessive first year post-release deaths of captive-raised male White-tailed Deer released in Texas (McCall et al. 1988) and among translocated wild deer in other studies (Jones and Witham 1990). Most deaths reportedly occurred within the first four months. Clearly, in our study, premature death of tagged deer (captive-raised or wild), for whatever reason, would reduce their numbers available to hunters in autumn.

Capture-related stress sustained in handling contributed to about 12% mortality among wild deer translocated in Illinois (Jones and Witham 1990). While we have no such data for deer we released in the wild, re-examination of data (1982–1991) for male deer returned to the enclosure revealed that 2 of 41 = 4.9% adult males and 7 of 57 = 12.3% male fawns died 1–21 days post-handling due to capture myopathy. Therefore, it seems reasonable to assume that the deer we released in the wild experienced even greater capture-related mortality, because of the added higher predator risk involved (Ozoga and Harger 1966).

Because of the generally severe winter climatic conditions in this northern region, some deer (mostly fawns and aged females, Ozoga 1972) die from malnutrition and predation each winter, and losses sometimes exceed 50 deer/km^2 (Verme and Ozoga 1971). Captive-raised fawns we released in autumn were probably especially ill-prepared, physiologically and behaviorally, to endure the severe winter climatic conditions characteristic of this region. Obviously, they had not attained optimal growth and/or essential fat reserves necessary for winter survival (Verme and Ozoga 1980) prior to release and lacked close social bonds with adult deer that tend to enhance winter survival of young deer (Ozoga 1972). Consequently, we believe that most autumn released fawns perished the first winter following release, which likely accounts for so few (2.4%) being harvested by hunters as antlered bucks.

Captive-raised male fawns released in spring were presumably in excellent physical condition, at least initially, averaging 18% heavier in body weight than their wild counterparts. Furthermore, spring-released deer were subjected to limited browse availability for only 1–7 weeks before snowmelt, which likely enhanced their prospects for overwinter survival. Nonetheless, compared to wild fawns, we suspect that even the spring-released captive-raised fawns suffered higher than normal first winter mortality, thus decreasing their numbers available for harvest by hunters.

Captive-raised deer (McCall et al. 1988), and even previously unhunted translocated wild deer (O'Bryan and McCullough 1985; Jones and Witham 1990), tend to be naive and exceptionally vulnerable to human-related mortality factors, such as deer-vehicle accidents, hunting, and probably poaching. Although part of another study (Verme 1988), 6 of 8 = 75% radio-transmitter equipped male deer, that were released or escaped from the Cusino enclosure when 1–3 years old, died within one year; five were shot by hunters and one was killed by an automobile (another was shot 19 months after release), which reflects the extreme vulnerability of captive-raised male deer to humans, even in Upper Michigan which has relatively sparse human population.

In view of the comparatively high (47.4%) hunter recovery of captive-raised male deer released when 1–3 years old, the disappearance of most (74.2%) captive-raised males released at older ages represents somewhat of an enigma. However, since all three of those recovered returned to, and were shot near (i.e., < 500 m) the enclosure where they were raised, we suspect that mature (> 3 years) males, in particular, had difficulty coping with relocation. Typically, mature bucks dominate younger subordinates and do most of the breeding in a given area (Hirth 1977). Due to fasting and strenuous rut-related activity, even mature enclosure bucks provided unlimited nutritious supplemental feed regularly lose 20–25% of their body weight during the autumn rut, whereas younger bucks normally only lose 10–18% (Ozoga, unpublished data). As a result, captive-raised mature bucks may have been at a distinct physiological disadvantage when released and/or had difficulty maintaining their high dominance status in the wild.

The principal reason for releasing captive-raised deer in the wild in this study was to reduce experimental deer herd size and make surplus deer available for legal harvest as an alternative to sacrificing them. We released enclosure-raised deer in March and April (annually), out of necessity, but timing the release of deer raised in small experimental pens was more variable. Our findings indicate considerable initial variation in survivability of captive-raised male deer released in Upper Michigan, dependent upon the time and age of deer when released.

Given our experience, the lowest non-hunting related death rate and greatest longevity can be expected for captive-raised male White-tailed Deer released when 1–3 years old. Also, in a northern climate, delaying the release of all captive-raised deer until shortly after complete snowmelt in spring may increase their survival rate during the first few months post-release. We acknowledge, however, that captive-raised male deer surviving translocation will be highly vulnerable to harvest by hunters, and few of them will survive longer than one year in the wild.

Acknowledgments

This paper is a contribution from Federal Aid in Wildlife Restoration Project W-117-R, Michigan, and the Cusino Wildlife Research Station. We thank C. S. Bienz, D. L. DeLisle, M. J. Donovan, L. J. Perry, and L. J. Verme in this endeavor.

Literature Cited

Hirth, D. H. 1977. Social behavior of White-tailed Deer in relation to habitat. Wildlife Monograph 53. The Wildlife Society Washington, D.C. 55 pages.

Jones, J. M., and **J. H. Witham.** 1990. Post-translocation survival and movements of metropolitan White-tailed Deer. Wildlife Society Bulletin 18: 434–441.

McCall, T. C., R. D. Brown, and **C. A. DeYoung.** 1988. Comparison of mortality of pen-raised and wild White-tailed bucks. Wildlife Society Bulletin 16: 380–384.

O'Bryan, M. K., and **D. R. McCullough.** 1985. Survival of Black-tailed Deer following relocation in California. Journal of Wildlife Management 49: 115–119.

Ozoga, J. J. 1968. Variations in microclimate in a conifer swamp deeryard in northern Michigan. Journal of Wildlife Management 32: 574–585.

Ozoga, J. J. 1969. Some longevity records for female White-tailed Deer in northern Michigan. Journal of Wildlife Management 33: 1027–1028.

Ozoga, J. J. 1972. Aggressive behavior of White-tailed Deer at winter cuttings. Journal of Wildlife Management 36: 861–868.

Ozoga, J. J., and **E. M. Harger.** 1966. Winter activities and feeding habits of northern Michigan Coyotes. Journal of Wildlife Management 30: 809–818.

Ozoga, J. J., and **L. J. Verme.** 1982. Physical and reproductive characteristics of a supplementally-fed White-tailed Deer herd. Journal of Wildlife Management 46: 281–301.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in White-tailed Deer. Journal of Wildlife Management 13: 195–216.

Ullrey, D. E., H. E. Johnson, W. G. Youatt, L. D. Fay, B. L. Schoepke, and **W. T. Magee.** 1971. A basal diet for deer nutrition research. Journal of Wildlife Management 35: 57–62.

Verme, L. J. 1973. Movements of White-tailed Deer in Upper Michigan. Journal of Wildlife Management 37: 545–552.

Verme, L. J. 1988. Niche selection by male White-tailed Deer: an alternative hypothesis. Wildlife Society Bulletin 16: 448–451.

Verme, L. J., and **W. F. Johnston.** 1986. Regeneration of Northern White Cedar deeryards in Upper Michigan. Journal of Wildlife Management 50: 307–313.

Verme, L. J., and **J. J. Ozoga.** 1971. Influence of winter weather on White-tailed Deer in Upper Michigan. Pages 16–28 *in* Proceedings of Snow and Ice Symposium. *Edited by* A. A. Haugen, Iowa State University.

Verme, L. J., and **J. J. Ozoga.** 1980. Effects of diet on growth and lipogenesis in deer fawns. Journal of Wildlife Management 44: 315–324.

Received 27 September 1991
Accepted 29 October 1992

Recovery Patterns of Ospreys, *Pandion haliaetus,* banded in Canada up to 1989

PETER J. EWINS [1,2] and C. STUART HOUSTON [3]

[1]Canadian Wildlife Service, Canada Centre for Inland Waters, 867 Lakeshore Road, P.O. Box 5050, Burlington, Ontario L7R 4A6

[2]Author to whom reprint requests and correspondence should be addressed.

[3]863 University Drive, Saskatoon, Saskatchewan S7N 0J8

Ewins, Peter J., and C. Stuart Houston. 1992. Recovery patterns of Ospreys, *Pandion haliaetus*, banded in Canada up to 1989. Canadian Field-Naturalist 106(3): 361–365.

This paper provides the first analysis of recoveries of Ospreys banded in Canada, covering the period 1951 up to 31 December 1989. The overall recovery rate of 3.7 % was considerably lower than for Ospreys banded in the United States or in Europe, possibly due to a reduced likelihood of finding a banded bird on many Canadian breeding areas, or geographical differences in hunting pressure. Migration routes and wintering areas of juveniles appeared to be broadly similar to those of U.S. Ospreys, with marked longitudinal segregation of birds reared in different regions of Canada. Shooting was the main reported mode of recovery and was more frequent in South and Central America than in North America, particularly since the 1970s.

Key Words: Ospreys, *Pandion haliaetus*, Canada, band recoveries, migration, mortality.

The Osprey, *Pandion haliaetus,* is one of the most widespread of bird species (Cramp and Simmons 1980; Poole 1989). In North America it breeds extensively from a line between central Alaska and Labrador, south to about 40°N, with coastal breeding populations extending south to Florida and the Gulf of California, but only scattered breeding populations inland in the U.S.A (Prevost 1983; Godfrey 1986). The Osprey's trophic position at the top of the aquatic food web resulted in marked population declines between the 1950s and 1970s in many parts of North America and Europe, due largely to eggshell thinning resulting from bioaccumulation of the organochlorine pesticide DDT and its derivatives (Wiemeyer et al. 1975, 1988). Although reliable census data are lacking for Canadian populations, other factors may also have caused more recent changes in Osprey numbers in Canada, notably acidification of lakes, human disturbance, persecution, and forestry management practices, but also the provision of artificial nesting-sites (see references in Poole 1989). There is now considerable public concern for this high-profile species.

In Canada, Ospreys are usually present for up to six months of the year, between April and October, but extremely little is known of the movements, distribution or biology of these birds outside the breeding season. However, recoveries of Ospreys banded in the USA have been analysed (Henny and Van Velzen 1972; Poole and Agler 1987; Santana and Temple 1987) This paper provides the first analysis of recovery data for Ospreys banded in Canada, and covers the migration routes, wintering areas, and causes of mortality, and discusses these aspects in relation to studies of other populations.

Methods

Records of all Ospreys banded in Canada between 1955 and 1989 (inclusive), as well as all recoveries reported up to 31 December 1989 were provided by the Bird Banding Office of the Canadian Wildlife Service in Ottawa. A relatively small number of birds appear to have been banded in Ontario before 1955 (as there are two recoveries from birds banded in 1951), but no records exist in the Bird Banding Office files. All recoveries reported up to the end of 1989 were used in the calculation of recovery rates. Recoveries were taken to include banded birds which were caught and released later [termed "returns" by Poole and Agler (1987)]. August 1 was taken as the start of the Osprey year, as most young fledge between mid-July and mid-August in Canada (Prevost 1977; Peck and James 1983; Royal Ontario Museum unpublished data; personal observations). Thus, a bird recovered in its first August was regarded as 1 month old, and in October it would be 3 months old, etc. Birds in their first year are termed juveniles, and those more than 24 months old are termed adults. Details were not complete for every recovery, so the sample sizes differed amongst some analyses. Recoveries of birds within the first month of fledging, and within the same 10' block of latitude and longitude where they were banded, were excluded from the analysis of movements.

Results

A total of 988 Ospreys had been banded in Canada up to 31 December 1989, 31 as adults and 957 (97%) as nestlings, in every province and territory except New Brunswick. The majority (97%) of these birds were banded since 1970, and mainly in Prince Edward Island (P.E.I.) and Nova Scotia (37%), Saskatchewan (28%) and British Columbia (22%) (Table 1). The 37 recoveries represent an overall recovery rate of 3.7%, with some variation evident among the provinces (Table 1).

Age at recovery

All but one of the recoveries were of birds banded as nestlings. Of the 34 recoveries of birds of known age, 19 (56%) were within the first 5 months (August-December), 25 (74%) in their first 12 months, 3 (9%) between 12 and 24 months old, and 6 (18%) were older than 24 months. Two birds in their third year of life were recovered in Nova Scotia during the summer months. Three Ontario-banded individuals were recovered as adults in Ontario during the summer months, aged 9 years, 12.2 years, and 15.9 years. The remaining adult recovery was aged 5.3 years, wintering in Brazil. In addition, a breeding female was caught at a nest in Saskatchewan in successive years, aged 13 and 14 years (personal observations).

Recovery locations

Of the 37 recoveries, 23 (62%) were from North America, 6 (16%) from Central America and the West Indies, and 8 (22%) from South America. The recovery locations and ages of the 28 birds recovered within their first two years of life are depicted in Figure 1. With the exception of the Prince Edward Island adult shot on a tributary of the Amazon in northern Brazil, recoveries of older birds, and those in the vicinity of the breeding areas are not shown.

Birds from Nova Scotia and Prince Edward Island were recovered during their first autumn migration (August-October) along the U. S. Atlantic coast, south to Florida, but one had reached the headwaters of the Orinoco River by October 10. Birds banded in Nova Scotia and P. E. I. were recovered in their first summer in Surinam (April) and the Dominican Republic (October). Two birds banded in western Ontario were recovered in September, due south of their natal areas, along the Mississippi River. Birds raised in central Saskatchewan and southwestern British Columbia appeared to follow a similar migration route in their first autumn, with recoveries along major U. S. river systems south to wetlands around the northwestern shores of the Gulf of Mexico. There was a cluster of recoveries of these western Canadian birds (3–17 months old) along the Pacific coast between El Salvador and northern Ecuador. A Saskatchewan Osprey recovered in October in southwestern Colombia had travelled at least 7000 km in its first 3 months. One bird banded in British Columbia was recovered in Florida sometime during the calendar year after fledging, constituting the only recovery of a Canadian Osprey on a different flyway from the banding site.

Three birds recovered as adults in Ontario between June and September were at least 200 km from the natal site (240 km E, 270 km ESE, and 760 km W). However, it was not possible to establish whether these birds were breeding or on migration at the time of recovery. In Nova Scotia, a bird banded as an adult was recovered three years later in April in the adjacent 10' latitude / longitude block, whereas another bird, in its third September, was recovered in Nova Scotia, over 200 km E of its natal site on P.E.I. The Saskatchewan female (aged 13–14 years), mentioned in the previous section, was breeding at a nest c.19 km WNW of its natal site.

TABLE 1. Numbers of Ospreys banded in different parts of Canada, with numbers recovered, up to 1989.

	Numbers banded			Recoveries	
Province/Territory	Nestling	Fully-grown[a]	Total	No.	%
Alberta	37	0	37	0	0
British Columbia	217	0	217	9	4.2
Northwest Territories	6	0	6	0	0
Manitoba	3	0	3	0	0
Newfoundland	5	1	6	0	0
Nova Scotia	45	10	55	3	5.5
Ontario	82	3	85	6	7.1
Prince Edward Island	305	0	305	8	2.6
Quebec	0	1	1	0	0
Saskatchewan	256	16	272	11	4.0
Yukon Territory	1	0	1	0	0
TOTAL	957	31	988	37	3.7

[a]All were banded as adults, except four hatching year birds in Nova Scotia, and two in Ontario.

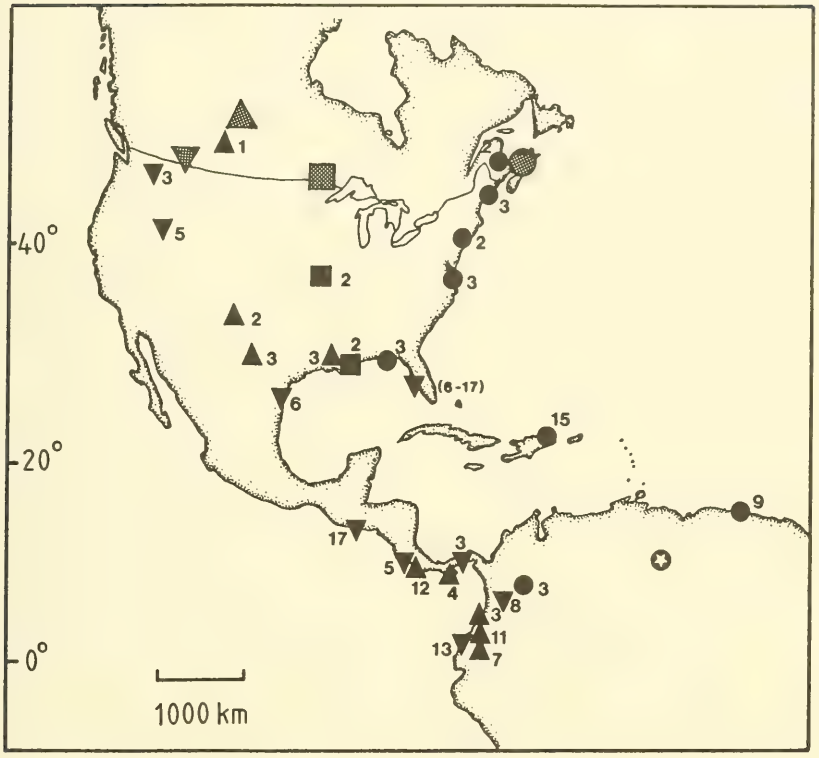


FIGURE 1. Recovery locations and ages (in months) at recovery of Ospreys banded as nestlings in Canada (1965-1989 inclusive). Recovery locations (filled symbols) refer to birds banded in areas designated by a stippled symbol of the same shape: British Columbia (▼), Saskatchewan (▲), Ontario (■), Prince Edward Island and Nova Scotia (●). ✪ designates a bird 5 years 3 months old. Recoveries in Canada are not shown.

Causes of mortality

The mode of recovery was reported for 36 birds: "Shot" (n=14); "Found dead" (12); "Injured" (6); "Dead on highway" (1); "Struck cables/tower" (1), "Entangled in fishing gear" (1), and "Band found in raptor/owl pellet or nest" (1). There was a significant geographic difference in the proportion of birds recovered which were reported as shot: 5 of 23 (22 %) recoveries in North America, but 9 of 13 (69%) in South and Central America, had been shot (G_1 = 7.98, $P<0.01$). Although sample sizes were not large, there was evidence for relaxation of persecution and hunting mortality of Ospreys in North America: birds were recovered as "Shot" between 1977 and 1989 in Central and South America, but only between 1963 and 1979 in North America.

Discussion

Despite the more extensive breeding distribution of Ospreys in Canada, far fewer birds have been banded here than in the United States (over 18 000 up to 1984: Poole and Agler 1987). To some extent this reflects a difference in the number and distribution of banders, as well as the remoteness of many nesting areas and the lower number of nests on accessible, man-made structures in Canada (Poole 1989; personal observations). Conclusions drawn from analyses of band recoveries must make allowance for various biases inherent in this form of reporting, such as spatial and temporal variation in the likelihood of a banded bird being found, killed, or reported (Newton 1979; Poole 1989). However, in the absence of more sophisticated techniques, band recoveries provide a useful source of information on movements and activities of birds away from their breeding areas.

The recovery rate of 3.7% is considerably lower than the 8.1% recorded for Osprey populations in the United States (Poole and Agler 1987), 11.0% for the U. K. (Mead and Clark 1989), and 12.4% for pooled European birds (but as high as 19.5% for Sweden and 16.8% for Finland) (Osterlof 1977). The reason for this difference is unclear at present, though the higher European recovery rate may reflect greater

hunting pressure, particularly on migration routes, at least until the introduction and enforcement of protective legislation in recent years. As we have included birds banded in the late 1980s in this calculation, some additional recoveries would be expected after 1989. However, 1988 and 1989 accounted for only 16% of the Canadian banding total, so this factor would explain only a relatively small part of the lower recovery rate of Canadian Ospreys. Only 15% of all Canadian recoveries were of adults in Canada during the breeding season, compared with corresponding figures of 35% for the U. S. (Poole and Agler 1987) and at least 28% for Europe (Osterlof 1977). Recovery rates within the first two years were similar for nestlings banded in Canada and the U. S., indicating that the chances of recovery to the south of North American breeding areas were similar for birds fledging at different latitudes. Therefore, this suggests that the likelihood of a banded Osprey being reported from breeding or staging areas within Canada may be much lower than elsewhere in the breeding range, probably due to the remoteness of many nests from human activity.

Overall, shooting was the main reported cause of mortality (39% of cases) of Canadian Ospreys, with more birds reported as shot in South or Central America than in North America, especially since the 1970s. Clearly, some birds reported as "found dead" may have been shot. Public education campaigns, increased legislative controls and general environmental concerns appear to have reduced the risk of Ospreys being shot in North America (Poole and Agler 1987), although heavier penalties might also have reduced the chances of a shot Osprey being reported.

Although the sample sizes are not large, the migration routes taken by Canadian Ospreys in their first autumn appear to be similar to those of populations breeding at similar longitudes in the United States (Henny and Van Velzen 1972; Melquist et al. 1978; Poole and Agler 1987; Johnson and Melquist 1991). Migration of this kind, on a 'broad front', has also been found amongst Osprey populations in Europe (Osterlof 1977). Major river systems are utilised by interior birds moving south, but Canadian Atlantic coast Ospreys seem to follow the coast en route to the West Indies (Santana and Temple 1987) and farther south. There was no evidence that these eastern Canadian populations 'leap-frogged' those breeding at lower latitudes. If anything, the absence of recoveries of eastern Canadian Ospreys south of the equator suggests they may winter, on average, further north than Ospreys from the north-eastern U.S. populations (Poole and Agler 1987). However, leap-frogging does seem to occur in western Canadian Osprey populations, although the sample sizes are still small. Saskatchewan and British Columbian birds winter in southern Central America and northwestern South America, as far south as the equator, farther south than the main wintering area (Mexico and central and western U.S) of western U.S. birds (Poole and Agler 1987; Johnson and Melquist 1991).

Within three months of fledging, the first juveniles are found on the wintering areas in South or Central America, or the West Indies, and these birds appear to remain there during at least their first 17 months of life. Although it was not possible to determine the age of first breeding from these Canadian data, the recoveries of two 3-year-old birds in Canada were consistent with results from the U.S., which showed that most birds first bred when 3–6 years old, depending on local conditions and individual differences (Poole 1989). Data from Loon Lake, Saskatchewan, suggests that some western Canadian Ospreys may settle to breed at greater distances from the natal site than has been found for north-eastern U.S. birds (see Poole 1989; Postupalsky 1989). Of 277 nestlings banded at Loon Lake between 1975 and 1991, only one (0.4%) returned to breed there (C. S. Houston, unpublished data). Ospreys in the western U. S. settled to breed at greater distances, on average, from the natal site than did those in the eastern U. S., probably due to the discontinuous distribution of suitable breeding habitat in the western states (Johnson and Melquist 1991).

In general, the timing and direction of movements of Ospreys banded in Canada are similar to those of migratory U. S. populations. The longitudinal segregation of birds in both their migration routes and wintering areas, following similar longitudinal separations in the Canadian breeding areas, has also been noted for U. S. Ospreys, similarly with only a small number of birds crossing into adjacent flyways (Poole and Agler 1984).

Acknowledgments

We are grateful to the Banding Office of the Canadian Wildlife Service for extracting the banding and recovery information, and to Ross James at the Royal Ontario Museum for permission to inspect nest record cards. Without the efforts of a small number of banders over the years, these analyses would not have been possible. In particular, we thank Randy Dibblee and Ron Ydenberg for permission to use their results. The librarians at the Canada Centre for Inland Waters, and the Canadian Wildlife Service (Ontario Region) provided administrative support, and the manuscript was kindly improved by Alan Poole, Chip Weseloh and Ron Ydenberg.

Literature Cited

Cramp, S., and **K. E. L. Simmons.** 1980. The Birds of the Western Palearctic, Volume II. Oxford University Press.

Godfrey, W.E. 1986. The Birds of Canada. National Museums of Canada. 595 pages.

Henny, C. J., and **T. Van Velzen.** 1972. Migration patterns and wintering localities of American Ospreys. Journal of Wildlife Management 36(4): 1133–1141.

Johnson, D. R., and **W. E. Melquist.** 1991. Wintering distribution and dispersal of northern Idaho and eastern Washington Ospreys. Journal of Field Ornithologists 62: 517–520.

Mead, C. J., and **J. A. Clark.** 1989. Report on bird-ringing for 1988. Ringing and Migration 10(3): 158–196.

Melquist, W. E., D. R. Johnson, and **W. D. Carrier.** 1978. Migration patterns of northern Idaho and eastern Washington ospreys. Bird-Banding 49: 234–236.

Newton, I. 1979. Population Ecology of Raptors. T. and A. D. Poyser, London.

Osterlof, S. 1977. Migration, wintering areas, and site tenacity of the European Osprey *Pandion h. haliaetus* (L.). Ornis Scandinavica 8: 61–78.

Peck, G. K., and **R. D. James.** 1983. The Breeding Birds of Ontario: nidiology and distribution.Volume 1: Nonpasserines. Life Sciences Miscellaneous Publications, Royal Ontario Museum, Toronto.

Poole, A. F. 1989. Ospreys: A Natural and Unnatural History. Cambridge University Press. 246 pages.

Poole, A. F., and **B. Agler.** 1987. Recoveries of Ospreys banded in the United States, 1914-1984. Journal of Wildlife Management 51: 148–155.

Postupalsky, S. 1989. Osprey. Pages 297–313 *in* Lifetime Reproduction in Birds. *Edited by* I. Newton. Academic Press, London.

Prevost, Y. A. 1977. Feeding ecology of Ospreys in Antigonish County, Nova Scotia. M.Sc. thesis, McGill University, Montreal, Quebec.

Prevost, Y. A. 1983. Osprey distribution and subspecies taxonomy. Pages 157–174 *in* Biology and Management of Bald Eagles and Ospreys. *Edited by* D. M. Bird. Harpell Press, Ste. Anne de Bellevue, Quebec.

Santana, E. C., and **S. A. Temple.** 1987. Recoveries of banded Ospreys in the West Indies. Journal of Field Ornithology 58(1): 26–30.

Wiemeyer, S. N., P. R. Spitzer, W. C. Krantz, T. G. Lamont, and **E. Cromartie.** 1975. Effects of environmental pollutants on Connecticut and Maryland Ospreys. Journal of Wildlife Management 39: 124–139.

Wiemeyer, S. N., C. M. Bunck, and **A. J. Krynitsky.** 1988. Organochlorine pesticides, polychlorinated biphenyls, and Mercury in Osprey eggs — 1970-79 — and their relationships to shell thinning and productivity. Archives of Environmental Contamination and Toxicology 17: 767–787.

Received 16 October 1991
Accepted 4 March 1992

Characteristics of Blackburnian Warbler, *Dendroica fusca*, Breeding Habitat in Upper Michigan

ROBERT V. DOEPKER[1], RICHARD D. EARLE[2] and JOHN J. OZOGA[3]

[1]Michigan Department of Natural Resources, Norway, Michigan 49870
[2]Michigan Department of Natural Resources, Houghton Lake Hts., Michigan 48630
[3]Michigan Department of Natural Resources, Shingleton, Michigan 49884

Doepker, Robert V., Richard D. Earle, and John J. Ozoga. 1992. Characteristics of Blackburnian Warbler, *Dendroica fusca*, breeding habitat in Upper Michigan. Canadian Field-Naturalist 106(3): 366–371.

Breeding habitat of the Blackburnian Warbler (*Dendroica fusca*) in the central Upper Peninsula of Michigan was investigated by locating singing males along random transects, and evaluating several habitat parameters at occupied sites. Blackburnian Warblers occupied natural, older age (60–167 years old), pole (12.5–24.9 cm, diameter breast height, dbh) and sawlog (25.0 + cm, dbh) size-class stands, located on mesic (upland) sites. Canopy closure approximated 80 ± 3.3%, with basal area (10.6 ± 1.3 m^2/ha) of conifer trees approximately 3-times greater than hardwoods (3.2 ± 0.5 m^2/ha). Stands were structurally and compositionally diverse with equal numbers of conifers and hardwoods in the seedling-sapling size class, however, conifers were 2-, 3- and 6-times more frequent in the pole, small sawlog and large sawtimber size-classes. If current forest management practices continue, we predict a decline in natural, mesic conifer forest types and, consequently, a reduction in suitable habitat for the Blackburnian Warbler in Upper Michigan.

Key Words: Blackburnian Warbler, *Dendroica fusca*, breeding habitat, census methods, Michigan.

Recent declines in neotropical migrant songbirds that breed in North America but migrate to South America to winter (Askins et al. 1990) have been attributed largely to forest fragmentation on the breeding grounds (Ambuel and Temple 1983) and destruction of moist-tropical forest wintering habitat (Terborgh 1989). Most investigations on the breeding grounds have been conducted in deciduous dominated forest regions, highly fragmented agricultural landscapes, or within large forest preserves exhibiting slow successional change (Lynch and Whigham 1984; Robbins 1979; Askins et al. 1990). Several bird species exhibiting regional population declines are associated with conifer dominated habitats (Terborgh 1989). The decline in neotropical migrants coincides with a reduction in natural conifer [(White Pine (*Pinus strobus*), Red Pine (*Pinus resinosa*), Eastern Hemlock (*Tsuga canadensis*), White Spruce (*Picea glauca*) and Balsam Fir (*Picea balsamea*)] habitat occurring on upland (mesic) sites in Upper Michigan (Cunningham and White 1941; Smith 1982; Spencer 1982), where this study was conducted.

This study was part of a monitoring plan developed for the Escanaba River State Forest (ERSF) Land Management Plan (Michigan Department of Natural Resources. 1988. DRAFT-ERSF Resource Management Plan. Lansing, Michigan). Our objectives were to: (1) quantify habitat conditions at sites occupied by Blackburnian Warblers, and (2) evaluate the impact of current forest management practices on the quantity and quality of breeding habitat for the Blackburnian Warbler.

Study Area and Methods

The ERSF (1704 km^2) is located within portions of Delta, Menominee, Marquette, and Alger counties (11 890 km^2) in central Upper Michigan. This large geographical area is heterogeneous due to local differences in bedrock, topography, soils, weather and disturbance history. Consequently, the area was divided into 40 Ecological Management Units (EMUs) that exhibited similar landscape scale (80–970 km^2), land use, and forest cover type patterns to facilitate management. This study was conducted within EMU-30 (673 km^2), which occupies a glacial lake plain adjacent to Lake Michigan, between the cities of Menominee and Escanaba. This EMU is a portion of the Escanaba subdistrict of the landscape ecosystems identified within Michigan (Albert et al. 1986). Eighty-two percent of the state land within EMU-30 is forested, 33% is lowland conifer and 8% mesic conifer, respectively (Table 1).

Forest management compartments (administrative units of 2.5–8.0 km^2) within EMU-30 were divided into four strata, based on the proportion of conifer cover types within each compartment. Conifer forest cover types included Northern White Cedar (*Thuja occidentalis*), White Spruce-Balsam Fir, Eastern Hemlock, White Pine, Red Pine, Black Spruce (*Picea mariana*), Tamarack (*Larix laricina*) and mixed swamp conifer (mixed stands dominated by conifers growing on lowland sites). Hardwood forest types included Aspen (*Populus* spp.), White Birch (*Betula papyrifera*), northern hardwoods [Sugar Maple (*Acer saccharum*); Yellow Birch (*Betula alleghaniensis*); White Ash (*Fraxinus americana*) and Elm (*Ulmus*

americana)] and lowland hardwoods [Red Maple (*Acer rubrum*) and Ash (*Fraxinus* spp.)].

EMU-30 was surveyed to locate singing male Blackburnian Warblers from 1 June-14 July 1989, using two-minute listening stops along randomly located transects. The starting points, and initial listening stops, of two paired transects (n=24) were located randomly within each compartment selected for sampling (H. Hill. 1986. Instructions for deer pellet group survey, spring 1986. Wildlife Division, Michigan Department of Natural Resources, Lansing, Michigan). Each transect consisted of eight, two-minute listening stops, at 100 m intervals, then offset 240 m perpendicular to the first leg of the transect, and eight stops parallel to the first eight stops. There were 16 stops per paired transect, for a total of 384 two-minute listening stops.

The Bitterlich, or plotless method (USDA 1975) using a 10-factor prism, was used to determine tree basal area. Trees were tallied by species, and a representative tree was selected and measured to estimate diameter at breast height (dbh) at each of the 384 stops, and from each male singing location centered on the singing tree. Tree age was determined by counting rings from a tree core obtained with an increment borer. These techniques are similar to those employed by foresters when conducting forest stand examinations (Michigan Department of Natural Resources. 1980. Operations inventory procedures-compartment and stand examination. Forest Management Division. Lansing, Michigan).

Chi-square analysis was used to test for differences between the observed and expected distribution of Blackburnian Warblers by habitat type. Habitat types were classified by identifying the dominant tree species group, size-class (seedling-sapling, <12.4 cm diameter at breast height; pole, 12.5–24.9 cm dbh; small sawlog, 25.0–37.4 cm dbh; or large sawlog, 37.5+ cm dbh), and density, (low, 0.9–3.6 m^2/ha; medium, 3.7–6.4 m^2/ha; or high 6.5 + m^2/ha). Differences were considered significant if $P \leq 0.05$.

To provide a more quantitative assessment of habitat conditions at male occupied sites, additional vegetation data were collected from 0.04 ha quadrats centered on the tree where the bird was heard singing during the survey, and at 10 locations where males were heard incidental to survey activities. Each corner of a 0.04 ha quadrat was located 14.1 m from the singing tree at 90°, 180°, 270° and 360°. The midpoint between the center and each corner was

TABLE 1. Forest cover type and size class (diameter at breast height, dbh) within Ecological Management Unit-30, as determined from standard forest inventory (March 1988), and 384 listening stops as part of a Blackburnian Warbler survey (1989), Escanaba River State Forest, Michigan.

	Operations Inventory				Blackburnian Warbler Survey			
Size Class (cm)	2.5–6.9	7.0–24.9	25.0+	Total	2.5–6.9	7.0–24.9	25.0+	Total
Forest Cover (%)								
Northern White Cedar	5	15	tr	20	0	10	4	14
Black Spruce	2	3	0	5	0	1	0	1
Tamarack	tr	0	0	tr	0	1	0	1
Mixed Swamp Conifer	3	5	tr	8	1	11	4	16
Total Lowland Conifer	10	23	tr	33	1	23	8	32
Spruce-Fir	0	2	tr	2	1	2	tr	3
Eastern Hemlock	0	2	1	3	0	1	1	2
Red Pine	tr	1	1	2	0	1	2	3
White Pine	tr	tr	1	1	tr	tr	1	1
Total Upland Conifer	tr	5	3	8	1	4	4	9
Total Conifer	10	28	3	41	2	27	12	41
Aspen	9	8	0	17	13	5	1	19
Paper Birch	0	1	0	1	0	1	0	1
Upland Hardwoods	tr	11	1	12	1	6	2	9
Total Upland Hardwoods	9	20	1	30	14	12	3	29
Lowland Aspen	2	2	tr	4	2	1	1	4
Lowland Hardwoods	1	6	tr	7	1	10	2	13
Total Lowland Hardwoods	3	8	tr	11	3	11	3	17
Total Hardwood	12	28	1	41	17	23	6	46
Total Non-Forested				18				13
Total				100				100

TABLE 2. Forest cover type, size-density class, and age of trees at sites occupied by Blackburnian Warblers, as determined from 0.04 ha quadrats centered on trees used by singing males within EMU-30, Escanaba River State Forest, Michigan.

Number of Singing Sites	Forest Cover Type	Size-Density[a]	Mean Age (yrs.)
3	Eastern Hemlock	Sawlog-high	167
3	White Spruce-Balsam Fir	Pole-high	64
2	White Pine	Sawlog-high	105
2	Northern White Cedar	Sawlog-high	104
2	Northern White Cedar	Pole-high	96
2	Eastern Hemlock	Pole-high	99
2	Upland Hardwood	Pole-high	109
1	Mixed Swamp Conifer	Sawlog-high	60
1	Red Pine	Sawlog-high	67
1	White Pine	Sawlog-medium	77
1	White Pine	Pole-high	85

[a]Size: Pole - 12.5-24.9 cm, dbh; Sawlog - 25.0+ cm, dbh; Density: Medium - 3.7-6.4m^2/ha; High - 6.5+ m^2/ha

marked, dividing the 0.04 ha quadrat into four, 10-m^2 quadrats. Density and basal area (m^2/ha) of trees (≥ 7.5 cm dbh) within the 0.04 ha plot were determined by counting and measuring dbh of individual trees with a diameter tape. A plot 4-m in radius was located at the center of each 10-m^2 quadrat to estimate understory vegetation (< 5 m in height) canopy coverage. Tree and understory canopy coverage were determined by estimating coverage to the nearest coverage class (0, 25, 50, 75 or 100%) within each of the four appropriate plots, and then averaging the four measurements. Ground coverage was determined at five equally spaced 1 m intervals marked on the rope used to locate the four corners of the 0.04 ha quadrat, and then averaging the five coverage classes from the total of 20 intervals. A clinometer was used to measure singing tree height, and average canopy height was determined by measuring a representative tree within each of the four, 10-m^2 quadrats and then averaging the four measurements.

Results

We heard 10 Blackburnian Warblers at 9 of 384 (2.3%) listening points. Vegetation information collected at these occupied sites and at 10 sites where birds were heard incidental to survey activities were pooled, because only one of seven vegetation variables differed significantly between the two groups (% tree canopy cover, Mann-Whitney test, $P < 0.05$). The proportion of forest estimated to be in hardwoods, conifers, and mesic conifers was similar for the Blackburnian Warbler survey and standard forest inventory data (Table 1).

Singing male Blackburnian Warblers were not found, nor have they been reported, using forest stands classified as seedling-sapling, or low density pole or sawlog size-classes. Therefore, we excluded these sites from statistical analysis. Ninety percent (n=18 of 20) of the stands occupied by Blackburnian Warblers were classified as conifer using the Bitterlich and 0.04 ha plot methods (Table 2). Blackburnian Warblers were more frequently associated with conifer than hardwood forest stands (Chi-square Test, $P<0.004$) and with sawlog-size verses pole-size conifer stands (Chi-square Test, $P<0.001$). The birds were distributed equally between sites classified as pole- and sawlog-size using the 0.04 ha plots, but a significantly larger proportion of the 20 occupied sites were classified sawlog-size using the Bitterlich method (McNemar test, $P<0.05$). The use of medium versus high density conifer stands were not significantly different (Chi-square Test, $P>0.05$).

Male Blackburnian Warblers occupied forest stands where dominant trees (based on basal area) ranged in age from 60 to 167 years old (Table 2). Occupied sites had high tree basal area and canopy cover, and low understory and herbaceous ground cover (Table 3). Conifer tree basal area was approximately 3-times that of hardwood tree species. Male birds usually sang from near the top of the tallest conifer trees, but there was no significant difference ($P>0.05$) between singing tree height and average tree canopy height. Habitat conditions at occupied sites were compositionally and structurally diverse, with similar numbers of hardwoods and conifers occurring in the seedling-sapling size-class. However, conifers were approximately 2-, 3-, and 6-times more numerous than hardwoods in the pole,

TABLE 3. Habitat characteristics obtained from 20, 0.04 ha quadrats centered on Blackburnian Warbler singing trees within EMU-30, Escanaba River State Forest, Michigan.

	Mean	Standard Error
Conifer Basal Area, m^2/ha	10.6	1.3
Hardwood Basal Area, m^2/ha	3.2	0.5
Tree Canopy Cover, %	80.1	3.3
Tree Canopy Height, m	16.4	0.6
Singing Tree Height, m	17.9	0.9
Understory Cover, %	15.8	2.9
Ground Cover, %	38.5	4.8

TABLE 4. Number of trees by diameter class (based on diameter at breast height, dbh) measured within 0.04 ha plots centered on Blackburnian Warbler singing trees located within EMU-30, Escanaba River State Forest, Michigan.

	Diameter Class (cm, dbh)				
Tree Species	7.5-12.4 Seedling-sapling	12.5-24.9 Pole	25.0-37.4 Small Sawlog	37.5+ Large Sawlog	Total
Hardwoods					
Aspen	11	14	8	0	33
White Birch	15	33	4	0	52
Ash	15	4	0	0	19
Northern Hardwood	6	5	0	1	12
Yellow Birch	2	5	2	1	10
Red Maple	21	36	10	3	70
Sugar Maple	24	4	3	1	32
Elm	2	4	0	0	6
Total Hardwoods	96	105	27	6	234
Conifers					
Balsam Fir	44	43	1	0	88
Northern White Cedar	13	48	28	1	90
Eastern Hemlock	39	65	26	19	139
White Spruce	6	21	1	1	29
Red Pine	0	7	2	3	12
White Pine	4	19	15	14	52
Total Conifers	96	203	73	38	410

small sawlog and large sawlog-size classes, respectively (Table 4).

Discussion

Our results agree with Beals (1960), Martin (1960), Titterington et al. (1979), Collins (1983) and Morse (1976, 1989) indicating Blackburnian Warblers use older, medium to high density, mesic conifer-dominated stands. Brewer (1967), Pettingill (1974), Erskine (1977) and Dawson (1978) report this species using lowland conifer forest stands, however, we found the bird only in conifer types on upland and transitional (upland-lowland) sites.

In 1935, Cunningham and White (1941) estimated that Pine (Red, White and Jack (*Pinus banksiana*)) and White Spruce-Balsam Fir forest cover types represented approximately 25% and 45%, respectively, of their original extent in the Upper Peninsula. Between 1935 and 1980, total forested land increased 8.3% in Upper Michigan, but mesic conifer acreage declined 19%. During this period, White Pine acreage remained static, Red Pine increased 305% and White Spruce-Balsam Fir acreage declined 36% (Cunningham and White 1941; Smith 1982; Spencer 1982). Eastern Hemlock was present in most northern hardwood stands in 1935 (Cunningham and White 1941); however, as a distinct type, it currently represents <1% of the commercial forest land in Michigan and Wisconsin (Eckstein 1980).

The White Spruce-Balsam Fir forest type currently represents approximately 69% of the mesic conifer habitat in the Upper Peninsula (Spencer 1982; Smith 1982). Management plans for the ERSF prescribe a 50-year rotation (interval between harvests) for White Spruce-Balsam Fir and mixed hardwood-conifer cover types (primarily Aspen-Balsam Fir). This cutting rotation is too short to allow the White Spruce-Balsam Fir component to mature and dominate a mixed stand (Westveld 1953; Johnston 1986) and the high level of mechanization used to harvest pulpwood kills most of the advanced White Spruce-Balsam Fir reproduction, effectively preventing an alteration of dominant cover types between rotations. We predict that accelerated harvesting will lead to a rapid decline in the amount of natural, mature mesic conifers, and an eventual decline in mesic conifers of all sizes. Silvicultural prescriptions appropriate to slow or reverse the loss of natural mesic conifers in Upper Michigan include: (1) lengthening harvest schedules in mixed conifer-hardwood stands, (2) leaving a residual canopy to reduce competition from hardwood sprouts, (3) leaving conifer seed-trees, and (4) using scarification or other site preparation to promote the establishment of conifer seedlings (Westveld 1953; Lancaster and Leak 1978; Lancaster 1985; Johnston 1986).

The distribution and abundance of the Blackburnian Warbler and several bird species associated with natural mesic conifer forest types are poorly represented in central Upper Michigan, where forest management for pulpwood production has been most intensive (Brewer et al. 1991). Mesic conifer management in Upper Michigan has empha-

sized the propagation of red pine in plantations. The simplified composition and structure of vegetation typical of intensively managed, even-age monocultures of red pine will not provide suitable habitat conditions for Blackburnian Warblers, or potentially, for other wildlife species associated with natural mesic conifer stands (Erskine 1977; Niemi et al. 1986; Cruz 1988; Bissonette et al. 1989; Santillo et al. 1989).

Acknowledgments

Jeffrey Gauthier, James Pohlson, and Elmer Olsen, Northland Audubon Society, Iron Mountain, MI, assisted in the Blackburnian Warbler surveys and collecting habitat information. We thank J. Stuht, T. Wiese, and R. Hess, Michigan DNR, Wildlife Division; T. Allen, Lake Superior State University; J. Hart, Michigan State University; and R. Brewer, Western Michigan University, for commenting on the manuscript. This work was supported in part by the Federal Aid in Wildlife Restoration Act under Pittman-Robertson project W-127-R.

Literature Cited

Albert, D., S. Denton, and **B. Barnes.** 1986. Regional landscape ecosystems of Michigan. School of Natural Resources, University of Michigan, Ann Arbor, Michigan. 32 pages.

Ambuel, B., and **S. A. Temple.** 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology 64: 1057–1068.

Askins, R. A., J. F. Lynch, and **R. Greenberg.** 1990. Population declines in migratory birds in eastern North America. Pages 1–57 *in* Current Ornithology. Volume 7. *Edited by* D. Power. Plenum Publishing, New York, New York.

Beals, E. 1960. Forest bird communities in the Apostle Islands of Wisconsin. Wilson Bulletin 72: 156–181.

Bissonette, J. A., R. J. Fredrickson, and **B. J. Tucker.** 1989. American marten: a case for landscape-level management. Pages 89–101 *in* Transactions of the 54th North American Wildlife and Natural Resource Conference. Wildlife Management Institute, Washington, D.C. 567 pages.

Brewer, R. 1967. Bird populations of bogs. Wilson Bulletin 79: 371–396.

Brewer, R., G. McPeek, and **R. Adams.** 1991. Atlas of Breeding Birds of Michigan. Michigan State University Press, East Lansing, Michigan. 594 pages.

Collins, S. L. 1983. Geographic variation in habitat structure of wood warblers in Maine and Minnesota. Oecologia 59: 246–252.

Cunningham, R. N., and **H. G. White.** 1941. Forest Resources of the Upper Peninsula of Michigan. USDA-Forest Service, Miscellaneous Publication 429. Lake States Forest Experiment Station, Washington, DC. 32 pages.

Cruz, A. 1988. Avian resource use in a Caribbean pine plantation. Journal of Wildlife Management 52: 274–279.

Dawson, D. K. 1979. Bird communities associated with succession and management of lowland conifer forests. Pages 120–131 *in* Management of north central and northeastern forests for nongame birds. *Edited by* R. DeGraaf and K. Evans. USDA-Forest Service, General Technical Report NC-51. North Central Forest Experiment Station, St. Paul, Minnesota. 268 pages.

Eckstein, R. 1980. Eastern hemlock in north central Wisconsin. Department Natural Resources, Research Report 104, Madison, Wisconsin. 20 pages.

Erskine, A. J. 1977. Birds in boreal Canada: communities, densities and adaptations. Canadian Wildlife Service, Report Series 41. Ottawa, Ontario. 71 pages.

Johnston, W. F. 1986. Manager's handbook for balsam fir in the North Central States. General Technical Report NC-111. USDA-Forest Service. North Central Forest Experiment Station, St. Paul, Minnesota. 27 pages.

Lancaster, K. H. 1985. Managing eastern hemlock-a preliminary guide. USDA-Forest Service. General Report NA-FR-30. Broomall, Pennsylvania. 5 pages.

Lancaster, K. F., and **W. B. Leak.** 1978. A silvicultural guide for white pine in the Northeast. General Technical Report NE-41. USDA-Forest Service. Broomall, Pennsylvania. 13 pages.

Lynch, J. F., and **D. F. Whigham.** 1984. Effects of forest fragmentation on breeding bird communities in Maryland, USA. Biological Conservation 28: 287–324.

Martin, N. D. 1960. An analysis of bird populations in relation to forest succession in Algonquin Provincial Park, Ontario. Ecology 41: 126–140.

Morse, D. H. 1976. Variables determining the density and territory size of breeding spruce-woods warblers. Ecology 57: 290–301.

Morse, D. H. 1989. American warblers: an ecological and behavioral perspective. Harvard University Press, Cambridge, Massachusetts. 406 pages.

Niemi, G. J., and **J. Hanowski.** 1986. Relationships of breeding birds to habitat characteristics in logged areas. Journal of Wildlife Management 48: 438–443.

Pettingill, O. S. 1974. Ornithology at the University of Michigan Biological Station and the birds of the region. Special Publication 1. Kalamazoo Nature Center, Kalamazoo, Michigan. 118 pages.

Robbins, C. S. 1979. Effect of forest fragmentation on bird populations. Pages 198–212 *in* Management of north-central and northeastern forests for nongame birds. *Edited by* R. DeGraaf and K. Evans. General Technical Report NC-51. USDA-Forest Service. North Central Forest Experiment Station, St. Paul, Minnesota. 268 pages.

Santillo, D. J., P. Brown, and **D. Leslie.** 1989. Response of songbirds to glyphosate-induced habitat changes on clearcuts. Journal of Wildlife Management 53: 64–71.

Smith, W. B. 1982. Timber resource of Michigan's Eastern Upper Peninsula, 1980. Resource Bulletin NC-64. USDA-Forest Service. North Central Forest Experiment Station, St. Paul, Minnesota. 103 pages.

Spencer, J. S. 1982. Timber resource of Michigan's Western Upper Peninsula, 1980. Resource Bulletin NC-60. USDA-Forest Service. North Central Forest Experiment Station. St. Paul, Minnesota. 102 pages.

Terborgh, J. 1989. Where have all the birds gone? Essays on the biology and conservation of birds that migrate to the American tropics. Princeton University Press, Princeton, New Jersey. 207 pages.

Titterington, R. W., H. S. Crawford, and **B. N. Burgason.** 1979. Songbird responses to commercial clear-cutting in Maine white spruce-balsam fir forests. Journal of Wildlife Management 43: 602–609.

United States Department of Agriculture. 1975. Timber Management Field Book. NA-MR-7. USDA-Forest Service. Northeastern Area, Broomall, Pennsylvania.

Westveld, M. 1953. Ecology and silviculture of the white spruce-balsam fir forests of eastern North America. Journal of Forestry 51: 422–430.

Received 30 December 1991
Accepted 1 June 1992

Schizaea pusilla, Curly-Grass Fern, an Addition to the Flora of New Brunswick

James P. Goltz[1] and Harold R. Hinds[2]

[1]126 Wilsey Road, Apt. 17, Fredericton, New Brunswick E3B 5J1
[2]Connell Memorial Herbarium, Biology Department, University of New Brunswick, Bag Service 45111, Fredericton, New Brunswick E3B 6E1

Goltz, James P., and Harold R. Hinds. 1992. *Schizaea pusilla*, Curly-Grass Fern, an addition to the flora of New Brunswick. Canadian Field-Naturalist 106(3): 372–375.

Schizaea pusilla is reported as an addition to the flora of New Brunswick. Its habitat at two New Brunswick localities is described and companion plants are listed.

Key Words: Curly-Grass Fern, *Schizaea pusilla*, New Brunswick flora, new record.

Except for the Curly-Grass Fern, *Schizaea pusilla* Pursh, members of the genus *Schizaea* are characteristic ferns of the Southern Hemisphere and tropics (Fernald 1950). In general, *Schizaea pusilla* has an Atlantic affinity, and according to Scoggan (1978), is known to occur in Nova Scotia; Newfoundland; St.-Pierre and Miquelon; Long Island, New York; and the pine barrens of southern New Jersey. Although a specimen is reputed to have been collected from Sauble Beach, Ontario, botanists remain somewhat sceptical of this record and have been unable to rediscover *Schizaea pusilla* at this site. If indeed it ever did grow there, it has likely been extirpated by cottage development (Cody and Britton 1989). Although it had long been suspected that *Schizaea* should occur in New Brunswick, there was no evidence that it had ever been observed in the province (Hinds 1986) prior to the summer of 1991 when it was discovered at two separate localities (Figure 1). *Schizaea pusilla* is reported here as an addition to the flora of New Brunswick.

On 31 July 1991, Cecil L. Johnston, David D. McCurdy and the first author found hundreds of plants of *Schizaea pusilla* (Figure 2) in the "power line bog", located about 1.8 km west of the north end of Chance Harbour, St. John Co., New Brunswick (45°08'N, 66°22'W). This locality is roughly 70 km NNW of the nearest known station near Digby, Nova Scotia and over 600 km northeast of the nearest known station in the United States. The plants were growing in open areas in a sphagnum fen complex, often in small wet depressions in black disturbed peat, as well as on low raised sedgy sphagnum mounds and in shallow peaty soil overlying low rocks (Figure 3). The plants were apparently concentrated at two main sites located within 100 m of one another and often grew in dense clumps. Fertile fronds ranged up to 6.8 cm in height. A list of companion plants found in the vicinity of the *Schizaea* is provided in Table 1. Measurements of the soil pH, taken on 12 September 1991 at six different sites where *Schizaea* was growing in the fen, ranged between 4.1 and 5.2*. Although the bedrock underlying the fen is purported to be precambrian basaltic and rhyolitic volcanics (Ferguson and Fyffe 1985), an abundance of *Thuja occidentalis* and the presence of *Potentilla fruticosa* in the fen suggest that there may be some calcareous influence.

Since the initial discovery was made close to a point at which a large powerline transected the fen, there was speculation as to whether or not the *Schizaea* may have been introduced into the site during the construction of the transmission line. However, in mid August 1991, *Schizaea* was discovered by C. L. Johnston and D. D. McCurdy at another location in the same fen, roughly 1 km from the site where it had first been found. This other location was close enough to the first site that both are represented on the map by the same dot.

On 25 August 1991, George H. Flanders Jr. and the second author discovered a large colony of *Schizaea* the vicinity of the Little Salmon River gorge, slightly to the east of the Little Salmon River, St. John Co., New Brunswick (45°31'N, 65°17'W). This station was roughly 95 km ENE of the Chance Harbour locality. Hundreds of plants of *Schizaea* were grow

*The pH measurements were made using a battery-operated pocket pH meter (pHep model; made by Hanna Instruments in Italy and distributed by Johns Scientific Inc., 175 Hanson St. Toronto, Ontario M4C 1A7). This instrument can measure pH ranges between 0 and 14, and is reported to have an accuracy of ±0.2 pH units. The accuracy of this instrument was confirmed using a 4.0 pH potassium biphthalate buffer solution and a 7.0 pH potassium phosphate monobasic-sodium hydroxide buffer solution (obtained from Fisher Scientific, Nepean, Ontario K2E 7L6). These buffers are reported to be accurate within ±0.01 pH units at 25°C.

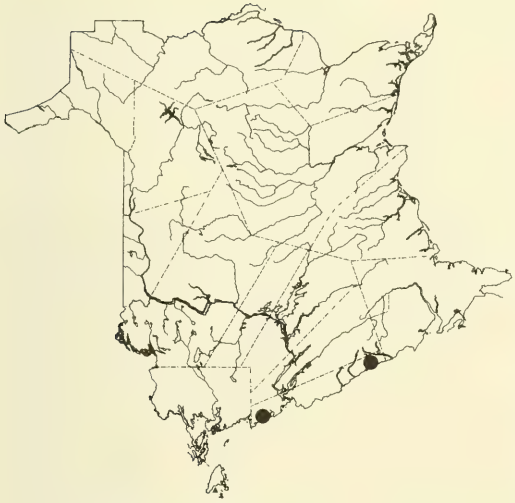


FIGURE 1. Distribution of *Schizaea pusilla* in New Brunswick. Solid circles represent new records reported herein. Scale:1 cm = 23 km (approximately).

ing in an open sphagnum bog, part of a complex of swamps and bogs which slowly drain over the edge of the Little Salmon River gorge. The habitat was similar to the Chance Harbour site except smaller and wetter, with some open pools. A list of vascular plants found in the vicinity of the *Schizaea* appears in Table 1. Several other similar bogs were examined in the general area but no other *Schizaea* were found. The bedrock underlying the Little Salmon River site is supposedly the same type as at the Chance Harbour site (Ferguson and Fyffe 1985).

At all localities where *Schizaea* has been discovered in New Brunswick, the habitat closely resembles sites in Newfoundland and Nova Scotia where the authors have seen this species. According to Roland and Smith (1969), *Schizaea* occurs in Nova Scotia in sphagnous bogs, peaty borders of lakes, sphagnous hollows and wet undrained depressions, and it is often abundant near the coast. Observations made at the New Brunswick localities for this species support Lellinger's generalization that *Schizaea* favours highly acid, humus-rich soil (Lellinger 1985).

Although it is possible that *Schizaea* has recently become established in New Brunswick, it is more plausible that it had been overlooked because of its inconspicuousness. Further exploration of suitable habitat, especially along the Bay of Fundy, may reveal that this species is more generally distributed than these collections indicate. *Schizaea* should be looked for in the more open bogs and fens where its

FIGURE 2. Photograph of *Schizaea pusilla* from the "power line bog" near Chance Harbour. Photograph taken by J. P. Goltz on 5 October 1991.

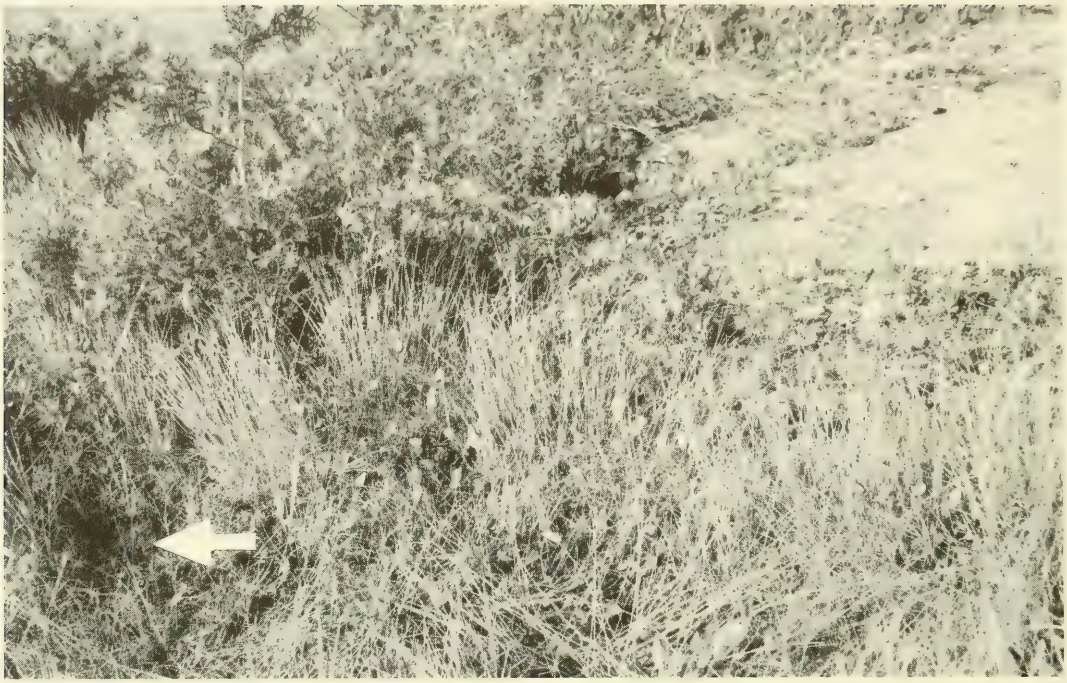


FIGURE 3. Photograph of typical *Schizaea* habitat at the "power line bog" near Chance Harbour. The arrow depicts the location of a colony of *Schizaea* plants. Photograph taken by J. P. Goltz on 5 October 1991.

TABLE 1. Companion plants generally located within 0.5 m of plants of *Schizaea pusilla*

Species	*Chance Harbour "power line bog"*	*Little Salmon River gorge bog*
OSMUNDACEAE		
Osmunda cinnamonea		X
PINACEAE		
Larix laricina		X
Picea mariana		X
POACEAE		
Calamagrostis pickeringii	X	
Muhlenbergia uniflora	X	X
CYPERACEAE		
Carex exilis		X
Carex pauciflora	X	
Eriophorum virginicum		X
Rhynchospora alba	X	
Scirpus caespitosus var. *callosus*	X	X
XYRIDACEAE		
Xyris montana	X	
LILIACEAE		
Smilacina trifolia		X
ORCHIDACEAE		
Calopogon tuberosus	X	X
Platanthera clavellata		X
Pogonia ophioglossoides	X	X
MYRICACEAE		
Myrica gale	X	
SARRACENIACEAE		
Sarracenia purpurea	X	X
DROSERACEAE		
Drosera intermedia	X	X
Drosera rotundifolia	X	X

(Continued)

TABLE 1: Continued

Species	*Chance Harbour "power line bog"*	*Little Salmon River gorge bog*
ROSACEAE		
Aronia melanocarpa		X
Rosa nitida		X
EMPETRACEAE		
Empetrum nigrum		X
ONGRACEAE		
Epilobium leptophyllum		X
ERICACEAE		
Andromeda polifolia	X	
Gaylussacia sp.	X	
Vaccinium macrocarpon	X	
Vaccinium oxycoccus		X
GENTIANACEAE		
Bartonia paniculata ssp. *iodandra*	X	X
LENTIBULARIACEAE		
Utricularia cornuta	X	
ASTERACEAE		
Aster nemoralis	X	X
Solidago uliginosa	X	X

companion plants (see Table 1) occur and where competition from ericaceous shrubs is minimal.

Voucher Material

Specimens of *Schizaea pusilla* collected from the two main localities on the dates of discovery reported above have been deposited at the Connell Memorial Herbarium of the University of New Brunswick (UNB) under the following collection numbers: Goltz, Johnston and McCurdy *1551* (Duplicate specimen sent to OAC); Hinds and Flanders *10,439*.

Schizaea was not collected from the other site discovered in the Chance Harbour area by Johnston and McCurdy in mid August.

Acknowledgments

The authors thank G. H. Flanders Jr., C. L. Johnston, D. D. McCurdy and Dr. A. W. Thomas for assistance in the discovery of the *Schizaea* stations and/or making subsequent field observations. The kind assistance of Dr. D. M. Britton in prereviewing the paper is also greatly appreciated.

Literature Cited

Cody, W. J., and **D. M. Britton.** 1989. Ferns and fern allies of Canada. Publication 1829/E. Research Branch, Agriculture Canada, Ottawa. 430 pages.

Ferguson, L., and **L. R. Fyffe.** 1985. Geological Highway Map of New Brunswick & Prince Edward Island. Special Publication Number 2. Published by the Atlantic Geoscience Society. Scale 1:638,000. Printed by Keystone Printing and Lithographing Ltd., Saint John, New Brunswick.

Fernald, M. L., 1950. Gray's Manual of Botany, Eighth edition. Dioscorides Press, Portland, Oregon. 1632 pages.

Hinds, H. R. 1986. The Flora of New Brunswick. Primrose Press, Fredericton, New Brunswick. 666 pages.

Lellinger, D. B. 1985. A Field Manual of the Ferns & Fern-Allies of the United States & Canada. Smithsonian Institution Press, Washington, D.C. 389 pages.

Roland, A. E., and **E. C. Smith.** 1969. The Flora of Nova Scotia. The Nova Scotia Museum, Halifax, N.S. 746 pages.

Scoggan, H. J. 1978. The Flora of Canada, Part 2. National Museum of Natural Sciences Publications in Botany 7(2). National Museums of Canada, Ottawa. 1711 pages.

Received 3 January 1992
Accepted 25 February 1992

Concentrations of Migrant Diving Ducks at Point Pelee National Park, Ontario, in Response to Invasion of Zebra Mussels, *Dreissena polymorpha*[1]

ALAN WORMINGTON and J. H. LEACH

Ontario Ministry of Natural Resources, Lake Erie Fisheries Station, Wheatley, Ontario N0P 2P0

[1]Contribution Number 92-01 of the Ontario Ministry of Natural Resources, Research Section, Fisheries Branch, Box 5000, Maple, Ontario L6A 1S9

Wormington, Alan, and J. H. Leach. 1992. Concentrations of migrant diving ducks at Point Pelee National Park, Ontario, in response to invasion of Zebra Mussels, *Dreissena polymorpha*. Canadian Field-Naturalist 106(3): 376–380.

The European Zebra Mussel, *Dreissena polymorpha* (Pallas), has recently invaded North America and is now well established in Lake Erie. Since 1988, larger-than-usual flocks of eight species of diving ducks were observed at Point Pelee during autumn migration. Maximum one-day counts of the principal species, Lesser Scaup, *Aythya affinis*, were up to 90 times historical counts. The ducks also remained in the area for a longer-than-normal period. Examination of gizzard contents of eight specimens and observations of feeding behaviour indicated that the ducks actively feed on Zebra Mussels. The availability of a new food source has led to this recent change in autumn migratory behaviour by several species of diving ducks. Distribution patterns of diving ducks in other areas of the Great Lakes may change as the Zebra Mussel expands its range.

Key Words: Zebra Mussel, *Dreissena polymorpha*, diving ducks, Lesser Scaup, *Aythya affinis*, predation, migration, Point Pelee.

The Zebra Mussel, *Dreissena polymorpha* (Pallas), a small bivalve mollusc native to Europe, is now well established in the Great Lakes region of North America. Adults of the mussel were first collected in Lake St. Clair in June, 1988, and in western Lake Erie in July 1988 (Hebert et al. 1989, 1991; Leach 1992). The initial introduction likely resulted from larvae discharged in ballast water in 1985 or 1986 (Griffiths et al. 1991). The mussel spread rapidly and by December 1988 was found along the north shore of Lake Erie as far east as the base of Long Point, a distance of 240 km from the mouth of the Detroit River. By the end of 1990 it had colonized all of Lake Erie and much of Lake Ontario and was found in harbours in the other Great Lakes. Spread of the mussel in North America is expected to be extensive and rapid (Griffiths et al. 1991; Strayer 1991; Neary and Leach 1992).

In Europe, *Dreissena polymorpha* is preyed upon by some species of fish and diving ducks (Stanczykowska 1977). There is considerable interest in North America in natural predation on the Zebra Mussel as a possible means of control. The purpose of this paper is to record the occurrence of predation on Zebra Mussels in Lake Erie by various diving ducks, and changes in autumnal migratory patterns in response to this new food resource.

Methods

The study area is Point Pelee National Park, Ontario (42°00'N, 82°30'W), which extends southward into Lake Erie (Figure 1). This well-known area has had a long history of bird observations, including that of diving ducks. Beginning in 1988, there was an increase in the numbers of diving ducks present at Point Pelee during fall migration (observations by Wormington and others), but only informal counts were made. Beginning in 1989, and continuing through 1991, systematic counts were conducted regularly during fall migration; the dense flocks routinely present in an area 5 to 6 km north of the Tip on the east side (East Beach) were monitored regularly. Data from 1988-1991 were compared to historical records, primarily from Stirrett (1973a, 1973b) and the seasonal summaries compiled since 1979 by A.W. for *American Birds* (National Audubon Society); supporting data for Stirrett (1973a, 1973b) were also consulted ("Stirrett Files", in storage at Point Pelee National Park).

To determine if the ducks were feeding on Zebra Mussels, we attempted to procure specimens caught in fishing nets and to obtain direct observations of feeding on Zebra Mussels.

The lake bottom in the study area consists of unconsolidated sediments including sand, mud, pebbles and cobbles (Coakley 1977). The hard surfaces in these sediments are colonized by Zebra Mussels (Leach 1992). To determine densities of Zebra Mussels on hard surfaces, counts were made from rocks selected randomly from the bottom of the study site (see Figure 1) by divers using SCUBA. The divers reported that all rocks encountered were covered with Zebra Mussels. Two subsamples from each rock were counted and measured; individual mussels were measured to the nearest mm.

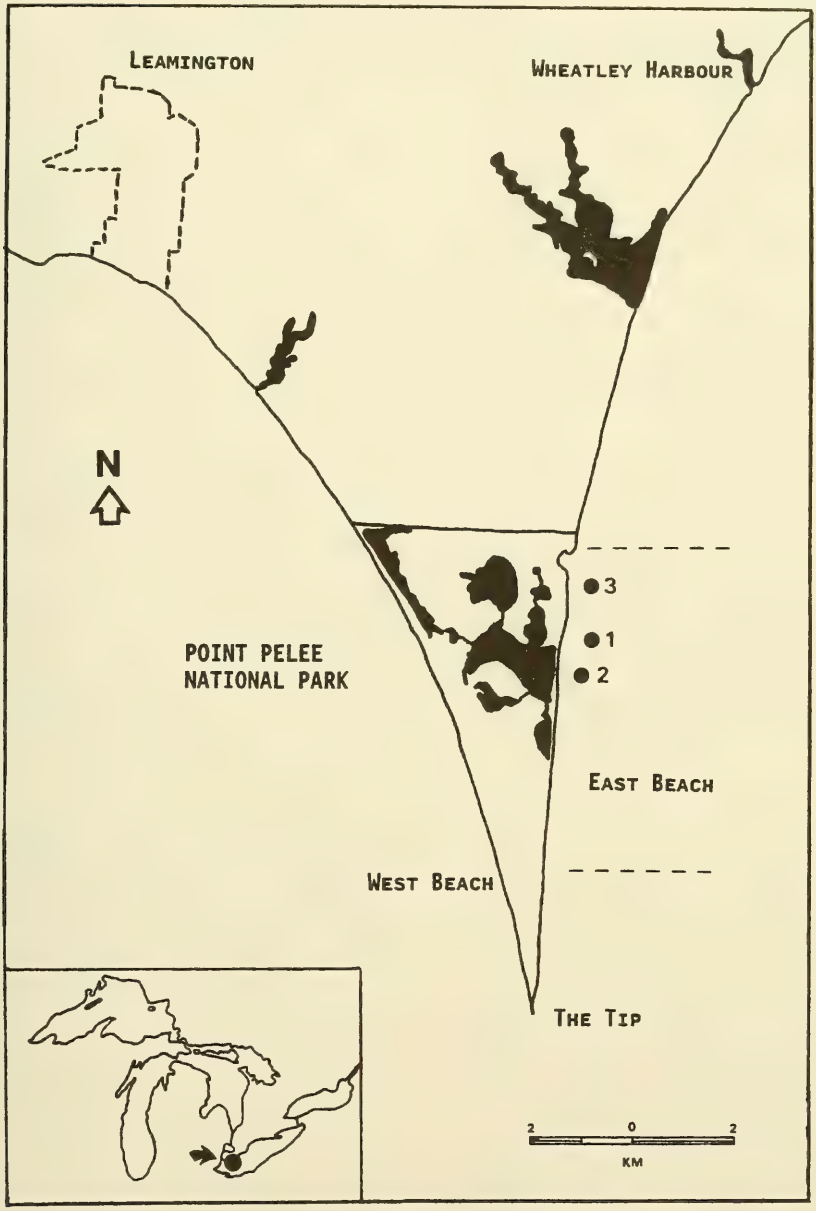


FIGURE 1. Map of study area (Point Pelee National Park, Ontario). Area between dashed lines represents usual limits of duck concentrations during 1989-1990. Sites of rock collections (1), duck collections by gillnets (2) and duck collections by shooting (3) are indicated.

Results

Duck counts

Over the course of the study (1988-1991) there were differences in the behaviour and location of diving ducks at Point Pelee during fall migration, as follows:

1988 — Early in the fall compact flocks of several species began to assemble at the extreme Tip, off the west side (Wormington, unpublished observations). By 20 October, record numbers of Black Scoter (for scientific names of diving ducks, see Table 1) and Surf Scoter had already assembled at the site, as did Lesser Scaup by 12 November (Table 1).

TABLE 1. Maximum one-day counts of diving ducks (excluding mergansers) during fall migration at Point Pelee National Park, pre-1988 and 1988-1991 inclusive.

Species	Pre-1988 maxima (year)	1988	1989	1990	1991
Canvasback *Aythya valisineria*	350 (1950)[a]	no data	8	5	21
Redhead *Aythya americana*	200 (1950)[a]	35	40	10	24
Ring-necked Duck *Aythya collaris*	12 (1985)	9	12	8	85
Greater Scaup *Aythya marila*	86 (1967)[b]	221	500	6500	1100
Lesser Scaup *Aythya affinis*	150 (1953)[c]	700	13500	11000	9900
King Eider *Somateria spectabilis*	2 (1970)	0	0	0	1
Harlequin Duck *Histrionicus histrionicus*	3 (1976)	1	1	0	0
Oldsquaw *Clangula hyemalis*	500 (1909)[d]	7	28	7	39
Black Scoter *Melanitta nigra*	36 (1971)	51	205	16	7
Surf Scoter *Melanitta perspicillata*	8 (1976)	95	110	61	3
White-winged Scoter *Melanitta fusca*	25 (1966)[e]	47	20	110	35
Common Goldeneye *Bucephala clangula*	1210 (1977)	388	1412	1800	366
Barrow's Goldeneye *Bucephala islandica*	no records	0	0	1	0
Bufflehead *Bucephala albeola*	128 (1951)	108	32	135	70
Ruddy Duck *Oxyura jamaicensis*	105 (1972)	45	55	19	20

[a] Both of these counts are exceptional and involved birds feeding inside Pelee Marsh; typical pre-1988 counts are similar to those of the 1988-1991 period.

[b] A one-day count of 350 birds (1950) is included in Stirrett (1973a), but the observation was published as "scaup species" by O'Reilly et al. (1951: 19); the birds were probably Lesser Scaup.

[c] A few counts exist (pre-1988) of "unidentified scaup" numbering 200 to 500 birds per day; the maximum count of 500 unidentified birds was obtained in 1957. All of these counts probably pertain to Lesser Scaup.

[d] This is an exceptional one-day count, made many years ago; the next highest daily count was 102 birds in 1974.

[e] Two higher counts exist: 200 birds on 18–24 January 1953 and 1005 birds on 24 December 1974. These are exceptional one-day counts (numbers were apparently not present earlier in the season), but probably represent birds overwintering on Lake Erie, rather than fall migrants; the brief appearance of these birds at Point Pelee was perhaps due to unfavourable ice conditions far offshore.

1989 — In 1989 there was both a major increase (Table 1) and a shift in location of diving ducks from that occupied in 1988. Most diving ducks were concentrated along the east shores of Point Pelee, with the majority at East Beach; concentrations on the west shore were considerably reduced from 1988.

1990 — The situation was little changed from 1989: the greatest concentrations of diving ducks were again at East Beach with few elsewhere. Frequent counts were obtained at East Beach through the fall of 1990 (Table 2).

1991 — A major change in distribution of diving ducks occurred in 1991. Numbers at East Beach were limited, the highest count (all species combined) totalled only 1400 birds (8 November); this compares with one-day counts here of well over 10 000 birds in both 1989 (30 November) and 1990 (27 December). In contrast, a major concentration assembled during 1991 at West Beach off Point Pelee at distances ranging from 1 to 3 km offshore; this flock peaked at approximately 10 000 birds in late October to mid-November.

Ducks feeding on Zebra Mussels

A total of eight duck specimens have been obtained from the study area. On 26 October 1990 one Greater Scaup and one Lesser Scaup were retrieved by ministry staff at East Beach from gillnets suspended one metre below the surface in water 9.8 metres deep. On 29 November 1991 six ducks (four Bufflehead, one Lesser Scaup and one Common Goldeneye) were collected by shooting (C.D. Ankney, University of Western Ontario), also at East Beach, specifically to examine gizzard contents (Diana J. Hamilton, personal communication). Gizzards of all eight birds contained the remains of Zebra Mussels with little or no other material present, except for grit.

Careful observation of both scaup species with a telescope during 1989-1990 at East Beach revealed that birds were diving for, obtaining, and feeding on Zebra Mussels. Typically birds would surface with a cluster of mussels and would manipulate them for 10–30 seconds, presumably to extract a desired food item.

Abundance of Zebra Mussels

We have no estimates of the area occupied by Zebra Mussels in the nearshore waters of Point Pelee. All solid substrates in the area appear to be heavily colonized. The stones collected by divers on 22 October 1990 had a mean population of 519 000 (S.D.=96 000; n=7) mussels m^{-2}. The populations on the stones were skewed in favour of small mussels with only about four percent with shell lengths

TABLE 2. Duck counts at East Beach of Point Pelee National Park, Fall 1990.

Species	31 Oct.	10 Nov.	25 Nov.	2 Dec.	9 Dec.	27 Dec.	31 Dec.	4 Jan.	13 Jan.
Canvasback	—	—	—	—	5	3	2	—	—
Redhead	10	—	5	—	5	—	1	1	—
Ring-necked Duck	8	—	—	—	1	—	1	—	—
Greater Scaup	200	800	800	300	300	6500	2700	1300	—
Lesser Scaup	2100	9000	4000	3500	4000	3500	1100	?	—
Black Scoter	6	6	1	—	—	—	—	—	—
Surf Scoter	25	25	12	—	—	11	2	—	—
White-winged Scoter	6	—	—	—	5	21	1	—	—
Common Goldeneye	200	350	450	40	100	1800	450	400	—
Barrow's Goldeneye	—	1	—	—	—	—	—	—	—
Bufflehead	20	—	25	—	—	64	60	—	—
Ruddy Duck	2	—	—	—	—	—	—	—	—
Total	2577	10182	5293	3840	4416	11899	4317	1701	0

10 mm or longer. We have no spatial estimates of mussel numbers in this area but assume that densities are less than those on rocky reefs near Pelee Island, which averaged 250 000 m^{-2} on 22 October 1990 (Leach 1992).

Discussion

The initial observations of duck flocks in 1988 were recognized as abnormal and unprecedented for the Point Pelee area. Since then, a major increase in birds observed during fall migration has developed involving Greater Scaup, Lesser Scaup, Black Scoter and Surf Scoter, and to a lesser degree for Ring-necked Duck, White-winged Scoter, Common Goldeneye and Bufflehead (Table 1). Before 1988, diving ducks (excluding mergansers, *Mergus* sp.) at Point Pelee usually flew past the Tip and rarely, if ever, lingered in the area; this was particularly true of the four species with the greatest increase of numbers.

Historically all of the indicated species occurred at Point Pelee during fall migration in substantially fewer numbers, as follows:

Greater Scaup — Before 1988, the few fall migrants recorded at Point Pelee were typically observed in flight past the Tip; usually less than 10 birds per day were recorded. The maximum one-day counts were 86 birds on 23 December 1967; 36 birds on 10 October 1949; and 20 birds on 12 October 1936.

Lesser Scaup — The past behaviour of this species was identical to that of Greater Scaup, with very limited numbers usually observed flying past the Tip. Before 1980 the maximum count ever attained was 150 birds on 25 November 1953, while during 1980-1987 the maximum was only 20 birds per day (in both 1980 and 1987). The increase in numbers has been astronomical, expanding from 20 birds in 1987 to 13 500 in 1989.

Black Scoter — Before 1988, only one or two individuals were usually recorded during fall migration at Point Pelee, with maximum counts in any one year limited to 5 to 9 birds per day. The all-time maximum counts were 36 birds on 24 December 1971 and 23 birds on 14 November 1985.

Surf Scoter — The past status of this species is similar to that of Black Scoter, except maximum daily counts were lower. The all-time maximum was 8 birds on 17 October 1976.

In the fall of 1988, the west side of the Tip was the only part of the lake at Point Pelee with concentrations of diving ducks (excluding mergansers). This can be correlated with the initial spread of Zebra Mussels into western Lake Erie at the time. As the Zebra Mussels were dispersing from the western end of the lake, settled mussels and larvae in 1988 were more frequent west of Point Pelee than on the east side (Griffiths et al. 1991; Leach 1992). By 1989, in correlation with the first concentration of birds at East Beach, Zebra Mussels were more numerous east of Point Pelee (Leach 1992). No obvious explanation is known for the change in diving duck distribution that occurred in 1991; a combination of the increased water turbidity due to excessive easterly winds, and/or an increase in mean size of Zebra Mussels at East Beach, may be factors. Draulans (1982) demonstrated that diving ducks in Europe have a preference for smaller Zebra Mussels, as did Hamilton (1992) at Point Pelee.

The normal diet of most diving ducks includes a high percentage of animal material, including molluscs. Palmer (1976) stated that the diet of both Lesser Scaup and Greater Scaup consists of about 50% animal (molluscs, crustaceans and insects) and 50% vegetable matter; for Surf Scoter and Black Scoter the corresponding figures are 90% animal and 10% vegetable. With the establishment of Zebra Mussels throughout most of the Great Lakes, a

change in the behaviour of migrant diving ducks during fall migration can be expected. Birds will undoubtedly concentrate and linger longer in the season at sites wherever Zebra Mussels are easily accessible; in addition to Point Pelee, this situation already exists at Long Point in Lake Erie (Jon D. McCracken and Richard W. Knapton, personal communication) and westernmost Lake Ontario (observations by Wormington and others). Availability of this new food source may increase survival and help to support larger populations of a species. However, it has been shown in Europe that captive Tufted Ducks (*A. fuligula*), fed with Zebra Mussels from a polluted lake, suffered numerous ill effects relating to reproduction (Scholten et al. 1989); the possibility of this happening in the Great Lakes should be investigated.

The impact of diving ducks on Zebra Mussel populations in the Great Lakes is anticipated to be very minimal, affecting local areas only to some degree. The availability of this new food resource is not limited to diving ducks; one of us (A.W.) has incidental observations (unpublished) of the following bird species feeding on Zebra Mussels at the surf line at Point Pelee: several species of "dabbling" ducks (*Anas* sp.), Hooded Merganser (*Lophodytes cucullatus*), American Coot (*Fulica americana*), Killdeer (*Charadrius vociferus*), Purple Sandpiper (*Calidris maritima*), Dunlin (*C. alpina*), Ring-billed Gull (*Larus delawarensis*), Herring Gull (*L. argentatus*), European Starling (*Sturnus vulgaris*) and Rusty Blackbird (*Euphagus carolinus*).

Acknowledgments

Donald G. Cecile assisted regularly on the counts that took place during 1989-1990. Diana J. Hamilton provided some supporting material on Zebra Mussel biology. We are grateful to John M. Casselman, Anthony J. Erskine, David J. T. Hussell, Stephen J. Nepszy and an anonymous reviewer for comments which improved the manuscript.

Literature Cited

Coakley, J. P. 1977. Processes in sediment deposition and shoreline changes in the Point Pelee area, Ontario. Scientific Series Number 79. Inland Waters Directorate, Canada Centre for Inland Waters, Burlington. 76 pages.

Draulans, D. 1982. Foraging and Size Selection of Mussels by the Tufted Duck, *Aythya fuligula*. Journal of Animal Ecology 51: 943–956.

Griffiths, R. W., D. W. Schloesser, J. H. Leach, and **W. P. Kovalak.** 1991. Distribution and dispersal of the zebra mussel (*Dreissena polymorpha*) in the Great Lakes region. Canadian Journal of Fisheries and Aquatic Sciences 48: 1381–1388.

Hamilton, D. J. 1992. The relationship between two predator groups, diving ducks and fish, and a novel prey item, the zebra mussel (*Dreissena polymorpha*), in Lake Erie at Point Pelee, Ontario. M.Sc. thesis, University of Western Ontario, London. 129 pages.

Hebert, P. D. N., B. W. Muncaster, and **G. L. Mackie.** 1989. Ecological and genetic studies on *Dreissena polymorpha* (Pallas): a new mollusc in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 46: 1587–1591.

Hebert, P. D. N., C. C. Wilson, M. H. Murdoch, and **R. Lazar.** 1991. Demography and ecological impacts of the invading mollusc *Dreissena polymorpha*. Canadian Journal of Zoology 69: 405–409.

Leach, J. H. 1992. Impacts of the zebra mussel, *Dreissena polymorpha*, on water quality and spawning reefs in western Lake Erie. Pages 381-397 *in* Zebra mussels: biology, impacts and control. *Edited by* T.F. Nalepa and D. W. Schloesser. Lewis Publishers Boca Raton, Florida. 810 pages.

Neary, B. P., and **J. H. Leach.** 1992. Mapping the potential spread of the zebra mussel (*Dreissena polymorpha*) in Ontario. Canadian Journal of Fisheries and Aquatic Sciences 49: 406–415.

O'Reilly, R. A., Jr., D. S. Middleton, N. T. Kelley, W. P. Nickell, and **C. J. Messner.** 1951. Bird Survey of the Detroit Region, 1950. Detroit Audubon Society. 67 pages.

Palmer, R. S. 1976. Handbook of North American Birds (Volume 3). Yale University Press, New Haven and London. 560 pages.

Scholten, M. C., E. Foekema, W. C. de Kock, and **J. M. Marquenie.** 1989. Reproduction Failure in Tufted Ducks Feeding on Mussels from Polluted Lakes. *In* Proceedings of the 2nd European Symposium on Avian Medicine and Surgery. Utrecht, Holland, 8–11 March 1989.

Stanczykowska, A. 1977. Ecology of *Dreissena polymorpha* (Pall.) (Bivalvia) in lakes. Polskie Archiwum Hydrobiologii 24: 461–530.

Stirrett, G. M. 1973a. The Autumn Birds of Point Pelee National Park, Ontario. Parks Canada, Ottawa. 36 pages.

Stirrett, G. M. 1973b. The Winter Birds of Point Pelee National Park, Ontario. Parks Canada, Ottawa. 28 pages.

Strayer, D. L. 1991. Projected distribution of the zebra mussel, *Dreissena polymorpha*, in North America. Canadian Journal of Fisheries and Aquatic Sciences 48: 1389–1395.

Received 17 January 1992
Accepted 21 March 1992

Notes

Brown Bear, *Ursus arctos*, Preying Upon Gray Wolf, *Canis lupus*, Pups at a Wolf Den

R. D. Hayes and A. Baer

Yukon Fish and Wildlife Branch, Department of Renewable Resources, Government of the Yukon, Box 2703, Whitehorse, Yukon Territory Y1A 2C6

Hayes, R. D. and A. Baer. 1992. Brown Bear, *Ursus arctos*, preying upon Gray Wolf, *Canis lupus*, pups at a wolf den. Canadian Field-Naturalist 106(2): 381–382.

Evidence suggests a Brown Bear (*Ursus arctos*) excavated a wolf (*Canis lupus*) den, then killed and ate four wolf pups that were inside.

Key Words: Gray Wolf, *Canis lupus*, Brown Bear, *Ursus arctos*, wolf den, bear predation, wolf pup mortality, Yukon Territory.

Hayes and Mossop (1987) summarized observations of Brown Bear (*Ursus arctos*) and Gray Wolf (*Canis lupus*) encounters at wolf dens in the Yukon Territory and Alaska. They concluded that bears sometimes excavated wolf dens and were potentially a threat to wolf pups. While conducting wolf research in the northern Yukon in 1989 we found evidence that a Brown Bear excavated a wolf den, then killed and ate four pups contained inside.

The den is located in sparse boreal forest in the northern Yukon near the Eagle River (137°17'W, 67°16'N), on the south side of a small, White Spruce (*Picea glauca*) knoll overlooking the Whitefish Lakes wetlands. The site includes three separate tunnels. One is on the south-west corner of the knoll four meters below the crest, another tunnel is located on the east side of the knoll and about 2 meters below the crest. The third, most heavily disturbed hole, is a horizontal shaft on the crest of the hill, about one meter in diameter and four meters long. All tunnels are located in the open, away from trees. A 12 member wolf pack raised pups at the den during 1988. The radio-collared breeding female was located at the den on 22 June 1989, suggesting she produced another litter. Contact with the pack was subsequently lost due to radio-transmitter failure.

The second author visited the site on 20 August 1989, and found the upper tunnel had been completely excavated, apparently by a bear. One lower tunnel was also excavated to a depth of 2–3 meters at the entrance but the nest chamber was not disturbed. Scattered around the den site were the uneaten remains of four wolf pup heads. The rear portion of each head had been eaten from the foramen magnum forward to the ramus of the lower jaw, and upwards to the rear of the sagittal crest. The brains were removed, but the skin and fur on the top and front of the skulls, noses and mandibles were uneaten. Age of the pups was estimated at about 8–10 weeks based on skull size. In the arctic, wolf pups are usually born between mid May and early June (Chapman 1978) indicating that the pups died sometime in late July or early August. Several bear scats containing wolf pup hair were found at the site. We believe the scats were from a Brown Bear because Black Bears (*Ursus americanus*) are rarely found in the northern Yukon.

Few observations of neonatal wolf mortality have been published. Williams (1990) observed wolves cannibalizing four pups at a den in the Northwest Territories, attributing the mortality to low food availability in the area that summer. Chapman (1978) recorded rabies killing all members of one denning pack in northern Alaska. It is likely that other diseases, including canine distemper virus, canine parvovirus, infectious canine hepatitis, Q fever and tularemia are also capable of killing wolf pups (Zarnke and Ballard 1987).

Brown Bears may be attracted to a wolf den to feed on cached carrion (Murie 1944) or to attempt to kill pups (Peterson et al. 1984; Lopez 1987; Hayes and Mossop 1987). Brown Bears have been seen digging at entrances of wolf dens containing pups in the presence of defending adult wolves (Murie 1944; Hayes and Mossop 1987). At the Eagle River den the pups were either killed by a bear or a bear scavenged their carcasses after they died from other causes. For the following reasons, we believe a bear killed the pups. First, if wolves killed the pups or the pups died from other causes, the adults would likely remove

them from the den area or bury them (Williams 1990). Second, the excavation by a bear suggests it was in search of live pups. Based on our inspection of 38 wolf denning situations in the Yukon where pups were raised, wolf denning chambers and tunnels are characteristically free of prey remains that could attract bears. Third, wolf pups will retreat into tunnels when alarmed (personal observation) and a bear would expect to find pups hidden inside.

During two summers that Williams (1990) studied arctic wolf denning behaviour, he found adults were absent 31% and 66% of the time. Wolf pups would be especially vulnerable to bear predation when adults are absent. Peterson et al. (1984) and Hayes and Mossop (1987) speculated that the greatest threat that bears pose to wolves would be at dens containing wolf pups. The evidence found at the Eagle River den, and observations of encounters between Brown Bears and wolves at other dens (Hayes and Mossop 1987) lead us to conclude that a Brown Bear excavated this den then caught and killed the pups hidden inside.

Bear predation on wolf pups in the arctic could be an important mortality agent for certain packs. Although it is not known to what extent wolf pups are preyed upon by bears in the arctic, the loss of an entire litter would cause a significant decline in the size of a wolf pack the following winter.

Acknowledgments

We thank Polar Continental Shelf Project for continued helicopter support to our studies in the northern Yukon. A. Harestad, R. O. Stephenson and D. H. Mossop reviewed an earlier draft of this paper.

Literature Cited

Chapman, R. C. 1978. Rabies: decimation of a Wolf pack in arctic Alaska. Science 201: 365–367.

Hayes, R. D., and **D. H. Mossop.** 1987. Interactions of Wolves, *Canis lupus*, and Brown Bears, *Ursus arctos*, at a Wolf den in the northern Yukon. Canadian Field-Naturalist 101: 603–604.

Lopez, B. 1987. Arctic Dreams: imagination and desire in a northern landscape. Charles Scribner's Sons, New York. 417 pages.

Murie, A. 1944. The Wolves of Mount McKinley. U.S. National Parks Fauna Series Number 5. Washington. 238 pages.

Peterson, R. O., J. D. Woolington, and **T. N. Bailey.** 1984. Wolves of the Kenai peninsula. Wildlife Monographs 88. 52 pages.

Williams, T. M. 1990. Summer diet and behaviour of Wolves denning on Barren-ground Caribou range in the Northwest Territories, Canada. MSc. thesis, University of Alberta. 75 pages.

Zarnke, R. L., and **W. B. Ballard.** 1987. Serological survey for selected microbial pathogens of Wolves in Alaska, 1975-82. Journal of Wildlife Diseases 23: 77–85.

Received 11 June 1991
Accepted 5 May 1992

Homing of Relocated Raccoons, *Procyon lotor*

JERROLD L. BELANT

State University of New York, College of Environmental Science and Forestry, Adirondack Ecological Center, Newcomb, New York 12852

Present address: U.S. Department of Agriculture, Denver Wildlife Research Center, 6100 Columbus Avenue, Sandusky, Ohio 44870

Belant, Jerrold L. 1992. Homing of relocated Raccoons, *Procyon lotor*. Canadian Field-Naturalist 106(3): 382–384.

Six Raccoons (*Procyon lotor*) were relocated 5.9 to 23.9 km from their initial capture site in northern New York. Of these, three Raccoons relocated 4 times between 4.2 and 17.8 km were recaptured 5 to 46 days later within 200 m of their previous capture sites. The remaining three Raccoons were not recaptured after being relocated ≤15 km from their capture sites. These observations document homing by Raccoons from distances up to 17.8 km.

Key Words: Homing, movements, *Procyon lotor*, Raccoon, relocation.

Although homing has been documented for a variety of mammalian carnivores (Carthy 1956; Egoscue 1956; Phillips and Mech 1970; Henshaw and Peterson 1974; Alt et al. 1977; Danner and Fisher 1977; Miller and Ballard 1982; Massopust and Anderson 1984), previous studies of relocations of Raccoons (*Procyon lotor*) have indicated a pattern of apparent random dispersal from the release site (Giles 1943; Wright 1977; Taylor 1979; Rosatte and MacInnes 1989; Tabatabai and Kennedy 1989). The only documented exception was a lactating female recaptured 3 km from the original capture site 95 days after release, a straight line distance of 23.4 km (Tabatabai and Kennedy 1989). Based upon diameters of home ranges of Raccoons (see summaries by Kaufman 1982 and Sanderson 1987), it is possible that this animal had returned to its previous home range. I provide information that confirms homing in

raccoons by documenting their return to the previous point of capture.

Study Area and Methods

The study was conducted in the Central Adirondack Ecological Zone (Will et al. 1982) of northern New York (UTM 564 000 m E, 4 870 000 m N) from April through June 1990. Elevations range from 460 m to 820 m. Overstory of this heavily forested area consists of second-growth northern hardwoods (72%), mixed hardwood-softwood (18%), and softwood (10%) (Simon 1979). Average annual precipitation (1986-1990) was 99 cm, including 253 cm of snowfall (Huntington Wildlife Forest [HWF], unpublished data). Mean January and July temperatures were -9 and 19°C, respectively (HWF, unpublished data).

Raccoons were captured in wire cage live traps (Models 207 and 209.5, Tomahawk Live Trap Company, Tomahawk, Wisconsin) baited with food scraps and/or lure. Traps were positioned adjacent to dwellings on HWF where Raccoons had been repeatedly observed foraging in garbage cans. Between two and six traps were set most nights from mid-April through mid-June. Upon capture, Raccoons were immobilized with a 5:1 mixture of 22.0 to 38.2 mg/kg ketamine hydrochloride (Ketaset®, Bristol Laboratories, Syracuse, New York) and 4.4 to 7.6 mg/kg xylazine hydrochloride (Rompun®, Mobay Corporation, Shawnee, Kansas). All Raccoons were ear tagged (Model 1005-3, National Band and Tag Company, Newport, Kentucky), weighed, sexed, and measured. Age (adult or juvenile) was determined by tooth wear (Grau et al. 1970). Raccoons were then transported various distances from the capture site and released upon full recovery. Data on movements were collected from recaptured individuals. Distances traveled by Raccoons were recorded as straight lines between the release and recapture sites.

Results and Discussion

Six Raccoons were captured initially and relocated 5.9 to 17.8 km from their original capture sites. Three of these raccoons were subsequently recaptured within 200 m of the original capture sites (Table 1). These three animals were relocated a second time from 4.2 to 23.9 km from the capture site and one was subsequently recaptured within 200 m of the initial capture site. Two other adult males and an adult female Raccoon released ≤15.0 km from their original capture sites were not recaptured.

As Raccoons were not monitored using radio telemetry, I was unable to determine whether animals that were not recaptured returned to their previous areas of capture. It is probable that some Raccoons will not be recaptured in the same type of set. Additionally, trapping was concluded during mid-June, when raccoon activity around human dwellings

TABLE 1. Movements of relocated Raccoons, central Adirondack Mountains, New York, 1990.

Raccoon Number	Sex/Age[a]	Date of original capture	1st relocation distance (km) and direction	1st recapture date near original capture site	2nd relocation distance (km) and direction	2nd recapture date near original capture site	3rd relocation distance (km) and direction	3rd recapture date near original capture site
1	M/J	21 April	5.9 W	8 June	23.9 E	not recaptured		
2	M/A	24 April	17.8 E	22 May	4.2 W	12 June	22.6 E	not recaptured
3	M/A	23 April	15.0 E	not recaptured				
4	M/A	24 April	15.0 E	not recaptured				
5	F/A	22 May	4.2 W	not recaptured				
6	F/A	2 June	5.9 W	7 June	20.0 SE	not recaptured		

[a]Sex: M = male, F = female. Age: J = juvenile, A = adult.

subsided. Therefore, it is possible that more Raccoons returned than I was able to document.

Straight line distances moved by raccoons in this study are not atypical. Dispersal distances by Raccoons released in unfamiliar areas have ranged from 0.1 to 295.0 km (Giles 1943; Priewert 1961; Lynch 1967; Wright 1977; Taylor 1979; Tabatabai and Kennedy 1989), though most of these did not involve animals homing to a certain location.

The mechanism(s) used for homing by raccoons in this study is unclear. Two potential mechanisms are the use of familiar odors or landmarks as cues. It is possible that the three Raccoons homing from 4.2 and 5.9 km away used one or both of these mechanisms; however, based on home range diameters of Raccoons (Kaufman 1982; Sanderson 1987), it is unlikely that the Raccoon returning from 17.8 km East of its previous capture site used these cues. Other potential homing mechanisms include random movements and expanding search patterns. Rogers (1986, 1987) concluded that these mechanisms did not explain homing in Black Bears (*Ursus americanus*). Use of random movements and expanding search patterns as homing mechanisms of Raccoons could be evaluated by monitoring their movements and activity patterns via radio telemetry. An investigator could then determine whether these movements occurred during the day or night, thus gaining insight as to whether solar or celestial cues were being used. One could also determine whether movements were directed or random, and whether Raccoons seemed to use an expanding search pattern. Additional studies are required to document adequately the mechanism(s) Raccoons use for homing.

Acknowledgments

I thank M.-K. W. Belant, C. M. Costello, C. L. Demers, K. M. Endres, R. Masters, and R. W. Sage, Jr. for assisting with field work. Two anonymous reviewers provided valuable comments for manuscript improvement. Material and logistical support was provided by the State University of New York College of Environmental Science and Forestry's Adirondack Ecological Center.

Literature Cited

Alt, G. L., G. J. Matula, Jr., F. W. Alt, and **J. S. Lindzey.** 1977. Movements of translocated nuisance black bears of northern Pennsylvania. Transactions Northeast Fish and Wildlife Conference 34: 119–126.

Carthy, J. D. 1956. Animal navigation. Charles Scribner & Sons, New York, New York. 151 pages.

Danner, D. A., and **A. R. Fisher.** 1977. Evidence of homing by a Coyote (*Canis latrans*). Journal of Mammalogy 58: 244–245.

Egoscue, H. J. 1956. Preliminary studies of the Kit Fox in Utah. Journal of Mammalogy 37: 351–357.

Giles, W. 1943. Evidence of Raccoon mobility obtained by tagging. Journal of Wildlife Management 7: 235.

Grau, G. A., G. C. Sanderson, and **J. P. Rogers.** 1970. Age determination of Raccoons. Journal of Wildlife Management 34: 364–372.

Henshaw, R. E., and **R. O. Peterson.** 1974. Homing in the Gray Wolf (*Canis lupus*). Journal of Mammalogy 55: 234–237.

Kaufman, J. H. 1982. Raccoon and allies. Pages 567–585 *in* Wild mammals of North America. *Edited by* J. A. Chapman and G. A. Feldhamer. John Hopkins University Press, Baltimore, Maryland.

Lynch, G. M. 1967. Long-range movement of a Raccoon in Manitoba. Journal of Mammalogy 48: 659–660.

Massopust, J. L., and **R. K. Anderson.** 1984. Homing tendencies of translocated nuisance Black Bears in northern Wisconsin. Proceedings of the Eastern Workshop on Black Bear Management and Research 7: 66–73.

Miller, S. D., and **W. B. Ballard.** 1982. Homing of transplanted Alaskan Brown Bears. Journal of Wildlife Management 46: 869–876.

Phillips, R. L., and **L. D. Mech.** 1970. Homing behavior of a Red Fox. Journal of Mammalogy 51: 621.

Priewert, F. W. 1961. Record of an extensive movement by a Raccoon. Journal of Mammalogy 42: 113.

Rogers, L. L. 1986. Homing by radio-collared Black Bears, *Ursus americanus*, in Minnesota. Canadian Field-Naturalist 100: 350–353.

Rogers, L. L. 1987. Navigation by adult Black Bears. Journal of Mammalogy 68: 185–188.

Rosatte, R. C., and **C. D. MacInnes.** 1989. Relocation of city Raccoons. Pages 87-92 *in* Ninth Great Plains Wildlife Damage Control Workshop Proceedings. United States Forest Service General Technical Report RM-171.

Sanderson, G. C. 1987. Raccoon. Pages 487–499 *in* Wild furbearer management and conservation in North America. *Edited by* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch. Ontario Trappers Association, North Bay, Ontario.

Simon, S. A. 1979. Vegetation classification and assessment of forest productivity in the Adirondacks. M.Sc. thesis, State University of New York, Syracuse. 169 pages.

Tabatabai, F. R., and **M. L. Kennedy.** 1989. Movements of relocated Raccoons (*Procyon lotor*) in western Tennessee. Journal of the Tennessee Academy of Science 64: 221–224.

Taylor, C. I. 1979. Movements, activities, and survival of translocated Raccoons in east Tennessee. M.Sc. thesis, University of Tennessee, Knoxville. 178 pages.

Will, G. B., R. D. Stumvoll, R. F. Gotie, and **E. S. Smith.** 1982. The ecological zones of northern New York. New York Fish and Game Journal 29: 1–25.

Wright, G. A. 1977. Dispersal and survival of translocated Raccoons in Kentucky. Proceedings Annual Conference Southeastern Association of Fish and Wildlife Agencies 31: 285–294.

Received 8 July 1991
Accepted 22 April 1992

Prey Delivered to Two Cooper's Hawk, *Accipiter cooperii*, Nests in Northern Mixed Grass Prairie

DANIEL J. PETERSON and ROBERT K. MURPHY

U.S. Fish and Wildlife Service, Lostwood National Wildlife Refuge, RR 2 Box 98, Kenmare, North Dakota 58746

Peterson, Daniel J., and Robert K. Murphy. 1992. Prey delivered to two Cooper's Hawk, *Accipiter cooperii*, nests in northern mixed grass prairie. Canadian Field-Naturalist 106(3): 385–386.

Avian prey, especially passerines, comprised 70% of the number of food items (n = 74) and 58% of dietary biomass delivered to Cooper's Hawk broods at two nests surrounded by mixed grass prairie, northwestern North Dakota. Mammalian prey made up the remainder.

Key Words: Cooper's Hawk, *Accipiter cooperii*, diet, predation, nesting, prairie, North Dakota.

Little is known of Cooper's Hawk (*Accipiter cooperii*) nesting ecology in prairie areas of the Northern Great Plains, where the hawk is rare to locally uncommon (e.g., Stewart 1975). In 1989 we observed prey delivered to two Cooper's Hawk nests at Lostwood National Wildlife Refuge (LNWR) in Burke and Mountrail counties, North Dakota (48°35'N; 102°25'W). Habitat within 2 km of nest "A" was composed of 70% mixed grass prairie with interspersed shrub (mainly *Crataegus* spp.) draws, 15% cropland, fallow, and hayland, 13% temporary and permanent wetlands, and 2% tree groves (0.1–1.0 ha Quaking Aspen [*Populus tremuloides*]). Habitat around nest "B" was similar but lacked shrub draws, had twice as much wetland area, and included four active farmsteads. Both nests contained four young; hatching dates were about 25 June (nest A) and 2 July (nest B). Observations were made from

TABLE 1. Prey delivered over nine days by adult Cooper's Hawks to broods at two nests, northwestern North Dakota.

Prey	n	% frequency	% biomass
MAMMALS			
Hare (*Lepus americana* or *townsendii*)[1]	2	2.7	8.8
Thirteen-lined Ground Squirrel (*Spermophilus tridecemlineatus*)	5	6.8	23.4
Mouse (*Peromyscus* spp. and unknown)[2]	10	13.5	5.4
Vole (*Microtus* spp.)	5	6.8	4.0
Total Mammals	22	29.7	41.6
BIRDS			
Passeriformes			
(9–25 g size class)			
incompletely identified	13	17.6	5.9
(26–40 g size class)			
incompletely identified	14	18.9	12.4
Western Kingbird (*Tyrannus verticalis*)	1	1.4	1.1
Gray Catbird (*Dumetella carolinensis*)	3	4.1	3.0
Northern Oriole (*Icterus galbula*)	1	1.4	0.9
(41–70 g size class)			
incompletely identified	13	17.6	19.2
Brewer's Blackbird (*Euphagus cyanocephalus*)	1	1.4	1.7
Brown Thrasher (*Toxostoma rufum*)	1	1.4	1.8
(71–127 g size class)			
incompletely identified	1	1.4	2.7
Miscellaneous birds			
American Coot (*Fulica americana*)[1]	1	1.4	4.3
Mourning Dove (*Zenaidria macroura*)	1	1.4	3.2
unknown	2	2.7	2.2[3]
Total Birds	52	70.3	58.4

[1]Hare and coot prey were small juveniles assigned approximate weights of 165 and 160 g, respectively.
[2]Unknown mice (n = 5) probably were *Peromyscus* spp. or *Zapus* spp.
[3]Biomass assigned unknown birds was based on the mean of weights assigned other bird prey observed (n = 50 items; $\bar{x}$ = 42 g).

30–45 minutes before sunrise until shortly after sunset, during 6-16 July and 19-23 July at nests A and B, respectively.

We observed nests from blinds placed 10 m (nest A) and 6 m (nest B) away and 1 m above, with a 20–40x spotting scope and 8x30x binoculars through one-way glass. Prey that could not be identified beyond Order were assigned to one of four size classes (9–25, 26–40, 41–70, and 71–127 g) based on our knowledge of similar-sized, known species, similar to Kennedy and Johnson's (1986) approach; mean weights of size class ranges were used to estimate biomass of prey therein. Biomass estimates of prey identified at least to genera were based on average weights of full grown specimens collected at LNWR and in Dunning (1984). We acknowledge having crude estimates of relative biomass because we could not assign precise weights to most prey delivered.

Adult Cooper's Hawks delivered 74 prey items in nine days of observation totalling 141.5 hours ($\bar{x}$ = 0.52 items/hour, SD = 0.15). Birds accounted for 70% of the items and about 58% of prey biomass delivered, and mammals comprised the remainder (Table 1). Most previous studies similarly reported a majority of avian prey in nesting season diets of Cooper's Hawks; due to methodological problems, however, numbers of birds reported in the hawk's diet may be biased high in studies not employing direct observation, so that generalizations about dietary makeup may be unwarranted (Bielefeldt et al. 1992). In our study, prey delivered while the young were less than three weeks old typically were well-plucked, decapitated, and eviscerated, making identification difficult as others have noted (e.g., Kennedy and Johnson 1986; Meng and Rosenfield *in* Palmer 1988). Small to medium-sized passerines (9-25 g through 41–70 g size classes), most (85%) of which could not be identified beyond Order, were most frequently delivered prey. We suspect the majority of these were sparrows (Emberizinae) and blackbirds (Icterinae), passerines common in surrounding habitat (Stewart 1975). Thirteen-lined Ground Squirrels contributed most as a species to biomass. Five incidental observations (RKM) of prey captures near other Cooper's Hawk nests at LNWR during 1983–1990 included two of blackbirds, an adult female Gray Partridge (*Perdix perdix*), a Thirteen-lined Ground Squirrel, and a vole.

Our observations hint that passerines and rodents are main prey of Cooper's Hawks nesting in northern mixed grass prairie. The hawks we studied were not in nesting habitat "typical" for the species (Brown and Amadon 1989; Rosenfield *in* Palmer 1988). But, when compared to other studies based on direct observation (summarized in Bielefeldt et al. 1992), our hawks used avian and mammalian prey roughly in the same frequency proportions as Cooper's Hawks living in the more wooded Great Lakes region of interior North America. We submit, however, that wetland prey such as Tiger Salamanders (*Ambystoma tigrinum*), ducklings, and juvenile coots, scarce in the 1989 drought year at LNWR, may occur more in the hawk's diet in years of average water availability as they do in diets of other area raptors (RKM, unpublished).

Acknowledgments

We thank M. T. Green and J. Norris for field assistance, and D. M. Becker, J. Bielefeldt, A. J. Erskine, P. L. Kennedy, W. B. McGillivray, M. Restani, and R. N. Rosenfield for helpful comments on drafts of the manuscript.

Literature Cited

Bielefeldt, J., R. N. Rosenfield, and **J. M. Papp.** 1992. Unfounded assumptions about diet of the Cooper's Hawk. Condor 94: 427–436.

Brown, L., and **D. Amadon.** 1989. Eagles, hawks and falcons of the world. Wellfleet Press, Secaucus, New Jersey. 945 pages.

Dunning, J. B., Jr. 1984. Body weights of 686 species of North American birds. Western Bird Banding Association Monograph Number 1. 38 pages.

Kennedy, P. L., and **D. R. Johnson.** 1986. Prey-size selection in nesting male and female Cooper's Hawks. Wilson Bulletin 98: 110–115.

Palmer, R. S. 1988. Handbook of North American birds. Volume 4. Yale University Press, New Haven, Connecticut. 433 pages.

Stewart, R. E. 1975. Breeding birds of North Dakota. Tri-college Center for Environmental Studies, Fargo, North Dakota. 295 pages.

Received 26 July 1991
Accepted 16 March 1992

Growth of Nestling Merlins, *Falco columbarius*

NAVJOT S. SODHI[1]

Department of Biology, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0
[1]Present address: Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9

Sodhi, Navjot S. 1992. Growth of nestling Merlins, *Falco columbarius*. Canadian Field-Naturalist 106(2): 387–389.

The growth of 20 nestlings from five broods of Merlins (*Falco columbarius*) was measured between 15 June and 3 July 1989, in Saskatoon, Saskatchewan. Nestlings were measured when they were between one and 17-d old. Gain in body mass and culmen length of presumed male and female nestlings diverged, after ten days of age, indicating sex-specific growth. All other morphological measurements (wing chord length, body length, middle-toe length, and tarsus length) were not different between sexes. Male and female nestlings on average gained 12.0 ± 0.5 and 14.8 ± 0.4 g each day, respectively. The nestings can be aged from 5 to 17d by using an equation: Age = (wing chord length + 22.482/8.568). The nestings can be sexed after they are five days old from measurements of wing chord and body mass.

Key Words: Merlins, *Falco columbarius,* nestling growth, aging nestlings, sexing nestlings, Saskatchewan.

I examined the growth of nestling Merlins (*Falco columbarius*) and present here techniques to age and sex them. Two studies have reported growth parameters of nestling Merlins. Picozzi (1983) measured 17 nestlings from six broods in Orkney (Britain). He provided a method to sex the nestlings but cautioned that because of size variation among different subspecies, his technique is best applicable to Merlins in Britain. Oliphant and Tessaro (1985) reported growth and food consumption of four hand-raised Merlin nestlings (two males and two females).

My aim was also to compare growth variables of the subspecies under study (*F. c. richardsonii*) with another subspecies *F. c. subaesalon* (Picozzi 1983) and with that of *F. c. richardsonii* raised in the laboratory (Oliphant and Tessaro 1985).

Methods

The research was conducted in Saskatoon (52°07'N, 106°38'W), Saskatchewan. The study area and history of Merlin breeding population have been described elsewhere (Sodhi et al. 1992).

Twenty nestlings from five broods were measured once every 4–6 d between 15 June and 3 July 1989. Based on differnt weight gain patterns (Picozzi 1983), 10 chicks were presumed to be males and 10 females. Each nestling was first measured when 1-d old or its age was estimated by observing pipped eggs and assuming the chicks to have hatched the following day (Newton 1979; Poole 1989). Individually numbered leg streamers were attached to each chick. These streamers were removed when the chicks were banded (between 10–14 d of age). No nestling was measured after 17 d of age because of the possibility of premature fledging.

Six measurements (body mass, body length, wing chord length, culmen length, middle-toe length, and tarsus length) were taken on almost every nestling. All nestlings were weighed using 100 or 300-g spring scales (± 1 g). No correction was made for crop contents. Culmen measurements (devoid of cere) were taken using a vernier calliper (± 1 mm). Wing chord lengths were determined using a plastic rule (± 1 mm) from the wrist to the distal end prior to feather emergence and thereafter from the wrist to the tip of the longest primary. Body lengths (head to the longest rectrices), middle-toe length (devoid of nails), and tarsus lengths were measured also using a plastic rule. One brood of five nestlings failed during these investigations (only two measurements were taken on these nestlings). The female was found dead about 1-km from the nest and the nestlings appeared to have starved to death.

Results

Body mass and culmen lengths of the presumed sexes appeared to have different distributions after the nestings were ten days old (Figures 1 A and B). Other variables did not show a bimodal distribution indicating little sexual dimorphism (Figure 1). Males on average gained 12.0 ± 0.5 (SE) g and females 14.8 ± 0.4 g each day ($t = 28$, $df = 18$, $p < 0.02$).

I developed a model for aging nestling Merlins using wing chord lengths. This was found to be the most reliable method to age chicks because: (1) wing chords can be more accurately measured compared to other body parts (Saunders and Hansen 1989), (2) food consumption by the chicks has minimal influence on wing chord lengths (Olsen et al. 1982), and (3) there was little sexual dimorphism in the wing chord lengths (males: $Y = 8.285\times + 4.342\times + 0.109 \times^2$; females: $Y = 8.615\ 3.566\times + 0.178\times^2$; $F = 0.55$, $dt = 2,24$, $p > 0.20$). The nestling age (d) of Merlins can be determined by using the following equation:

$$AGE = \frac{WCL + 22.482}{8.568}$$

Nestlings can be aged between 5 and 17 d by using this equation as measurements of the nestlings

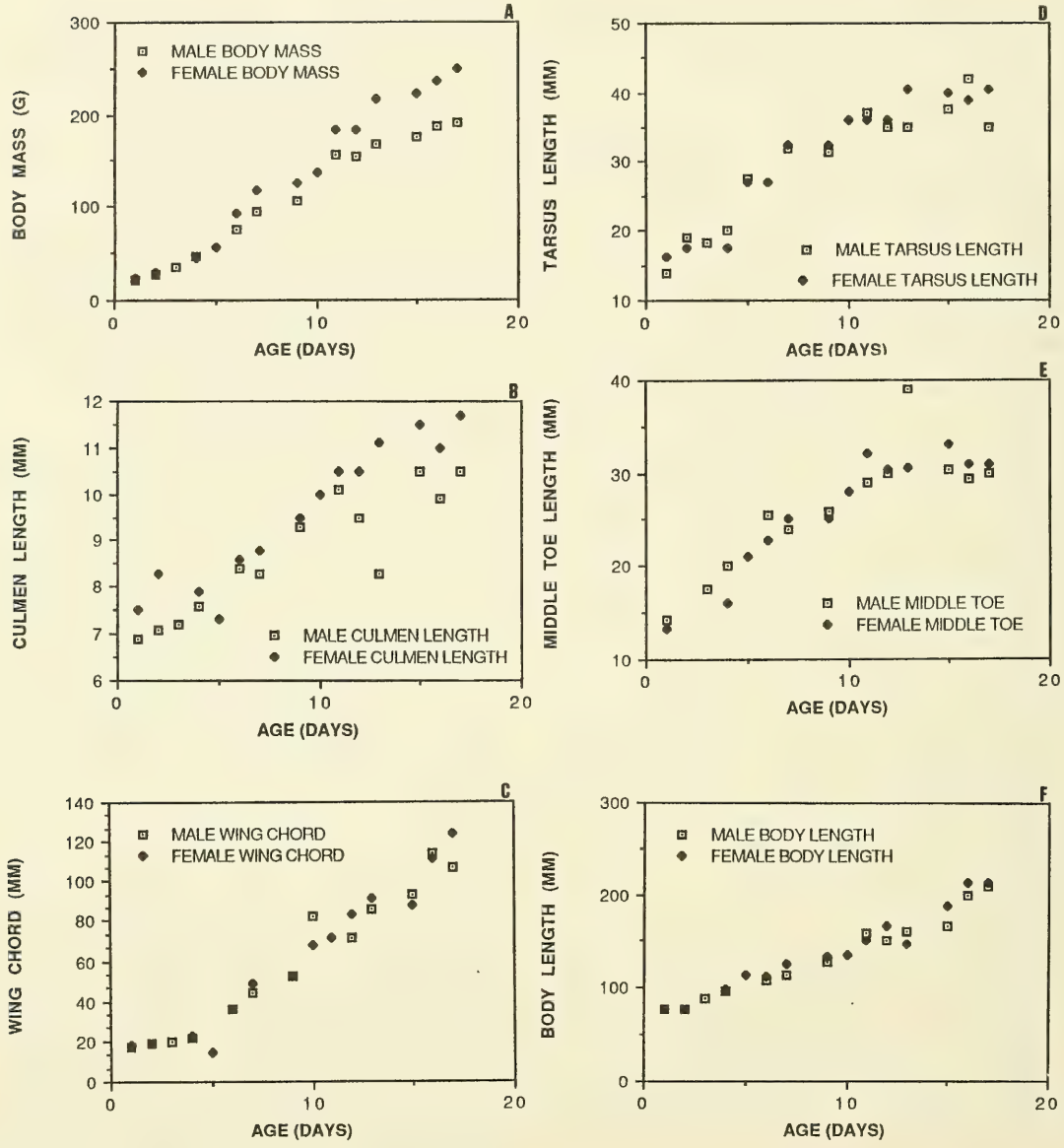


FIGURE 1. Mean growth curves for ten male and ten female Merlin nestlings. A = body mass; B = culmen length; C = wing chord length; D = tarsus length; E = middle toe length; and F = Body length.

between this linear growth period of the wing chord length were used to obtain the above equation. The 95% confidence limits for age estimates using the equation are ± 1.7 d.

The nestlings can be sexed by measuring wing chord lengths and body weights (Figure 2). The sexes can be fairly accurately estimated when the chicks weigh about 50 g and have wing chords of about 30 mm, which they attain when they are five days old.

Discussion

Compared to growth rates with *F. c. subaesalon* nestlings (Picozzi 1983), *F. c. richardsonii* nestlings grew slightly faster. At 17 d, on average, *richardsonii* and *subaesalon* males were 192 and 180 g (estimated from Figure 2 in Picozzi 1983), respectively. The *richardsonii* and *subaesalon* females were, on average at 17 d, 250 and 230 g (estimated from Figure 2 in Picozzi 1983), respectively. This

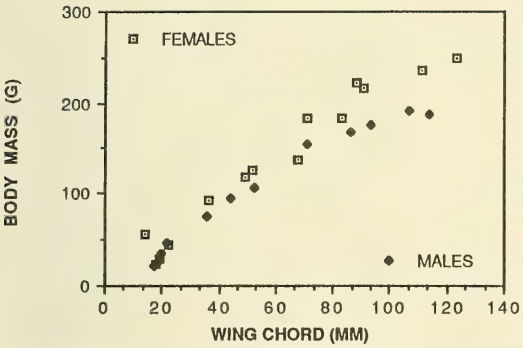


FIGURE 2. Relationship between wing chord length and body mass in male and female Merlin nestlings.

difference probably is due to the size difference between the adults of these two subspecies. The wild *richardsonii* chicks also grew faster than hand-raised nestlings. At 17 d, the hand-raised males weighed on average about 140 g (Oliphant and Teasaro 1985), 52 g less than their wild counterparts. The hand-raised females at 17 d on average were 200 g, 50 g less than the wild nestlings. Many factors may explain the faster growth of the wild nestlings; e.g., quality of the food or lack of parental nasal gland fluid in the food of the hand-raised chicks (Oliphant and Tessaro 1985; Oliphant 1988).

The small sample sizes and nonindependent data sets may have underestimated variation in the method given by me for sexing Merlin nestings. I believe, however, that the methods given by me to age and sex Merlin nestlings can be used for *richardsonii* chicks in North America.

Acknowledgments

I thank Geoff Peat for field assistance. I am also grateful to Paul C. James, Ian G. Warkentin, Lynn W. Oliphant, Christer G. Wiklund, Kim G. Poole, C. Stuart Houston, Tony Erskine, and an anomymous reviewer for commenting on an earlier draft. Financial support for this study was provided by a Natural Sciences and Engineering Research Council of Canada grant to Lynn W. Oliphant.

Literature Cited

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion.

Oliphant, L. W. 1988. Effect of saline added to food on weight gain of hand-raised falcons. Journal of Raptor Research 22: 119–120.

Oliphant, L. W., and **S. Tessaro.** 1985. Growth rates and food consumption of hand-raised Merlins. Raptor Research 19: 79–84.

Olsen, P. D., J. Olsen, and **N. J. Mooney.** 1982. Growth and development of nestling Brown Goshawks (*Accipiter fasciatus*), with details of breeding biology. Emu 82: 189–194.

Picozzi, N. 1983. Growth and sex of nestling Merlins in Orkney. Ibis 125: 377–382.

Poole, K. G. 1989. Determining age and sex of nestling Gyrfalcons. Journal of Raptor Research 23: 45–47.

Saunders, M. B., and **G. L. Hansen.** 1989. A method for estimating the ages of nestling Northern Harriers (*Circus cyaneus*). Canadian Journal of Zoology 67: 1824–1827.

Sodhi, N. S., P. C. James, I. G. Warkentin, and **L. W. Oliphant**. 1992. Breeding ecology of urban Merlins (*Falco columbarius*). Canadian Journal of Zoology 70: 1477–1483.

Received 9 August 1991
Accepted 27 March 1992

Western Catalpa, *Catalpa speciosa*, Colonising in Toronto, Ontario

C. S. CHURCHER

Department of Zoology, University of Toronto, Toronto, Ontario, Canada M5S 1A1 *and* Department of Vertebrate Palaeontology, Royal Ontario Museum, Toronto, Ontario, M5S 2C6

Churcher, C. S. 1992. Western Catalpa, *Catalpa speciosa*, colonising in Toronto, Ontario. Canadian Field-Naturalist 106(3): 390–392.

Three young specimens of *Catalpa speciosa* or Western Catalpa are present in the North Rosedale Ravine and Don Valley Brickyard pit. They are between 6 and 8 years old, presumably result from fertile self-seeding from ornamental plantings in Rosedale, and one flowered in June, 1991. This appears to be the first record of this species escaping from plantings in the Toronto area.

Key Words: *Catalpa speciosa*, Western Catalpa, Toronto, colonising.

The North American catalpas (*Catalpa speciosa* and *C. bignonioides*) are probably not native to Ontario (Bonner and Graney 1989), and certainly not to the Toronto Region. Both Western (*C. speciosa*) and Eastern (*C. bignonioides*) catalpas have been planted in southern Ontario along the north shore of Lake Erie and in towns in the better climatic areas. Cruise (1969), Dodge (1914, 1915) and Scoggan (1979) report *C. speciosa* persisting in Essex County (Dodge 1914; Morton and Venn 1990). The occurrence of colonising individuals in Toronto is noteworthy and represents a significant extension of suitable habitat and seeding success, although it may be an isolated instance and reflect the "city effect". Elsewhere, over most of Ontario, catalpas fail to produce viable seed and exist as planted ornamentals only.

Observations

The Western Catalpa (*Catalpa speciosa*) is present as three self-seeded individuals in the Rosedale area of Toronto. Both the Western and Eastern or Common Catalpa (*C. bignonioides*) are present as plantings in North Rosedale, e.g., a Western in Chorley Park and an Eastern at 173 Glen Road just south of Summerhill Avenue. Thus a readily available seed source for both species is available in the area.

Don Valley Brickyard Specimens

Two young individuals are located on the edge of a shale slope by an old road on the eastern wall of the Don Valley Brickyard, about 100 m north of Chorley Park and to the east of a stream and the old Beltline right-of-way (Figure 1). The larger individual was about 7-8 years old from counted nodes, about 4 m high, and growing well in 1991. The smaller is about 10 m south of the larger, about 6-7 years old, but only about 1.5 m high.

The larger individual has nodes between 300 and 400 mm long, average = 356 mm, and leaves up to 300 mm long and 230 mm wide, including the acuminate tip. The shape of the leaves agrees best with those of *C. speciosa*. In shape they are tapered acuminate-ovate or acuminate-cordate, with a prominent tapered acuminate tip (Scoggan 1979). The undersides are pubescent. There are no signs of lateral points to the leaves. Comparison with the Glen Road *C. bignonioides* and the Chorley Park *C. speciosa* show that the former usually has sloping or rounded shoulders to the leaf near the petiole while the latter has shoulders that project above the junction of the petiole and blade. Both have pubescent undersurfaces to the leaves, but the latter is distinctly more so and the hairs appear longer, especially over the petiole. The tips of the leaves are more pointed and tapered in *C. speciosa* (Scoggan 1979). The larger leaves of the larger Brickyard specimen reach over 300 mm in length along the main midrib, with maximum widths greater than 200 mm, for a mean value of Length:Breadth ratios of 1.28 (N = 25; B:L = 0.786).

The leaves of the Glen Road *C. bignonioides* reach 270 mm in length along the main rib, with maximum widths usually across the secondary points about 240 mm, with one exceptionally broad at 288 mm. The mean value of the Length: Breadth ratio was 1.278 (N=25; B:L = 0.783). Thus the shapes of the leaves fall within a rectangle 1.28 long by 1.00 broad in both species, but the additional points and their less acuminate points make the leaves of *C. bignonioides* appear blunter or fuller than those of *C. speciosa.*

The first flowering of the larger individual was noted in June, 1991, in concert with that of the planted *C. speciosa* in the southeast of Chorley Park. Its flowers are white, with two yellow ventral stripes, and rows of purple-brown spots between the stripes and flanking them, on the lower three lobes. The spread corolla wings measure 45-55 mm, and there is a distinct notch on the ventral lip in the midline. These characters agree with Scoggan's (1979) description.

The smaller individual has leaves that are also strongly acuminate and pubescent underneath, but many of its leaves show the secondary points at the

FIGURE 1. Young Western Catalpa (*Catalpa speciosa*) growing in the Don Valley Brickyard, Toronto, June, 1991. Note flowers (arrow) on left hand specimen and three-pointed leaves on right hand specimen. The Don Valley Formation type section is visible in the background.

ends of the two main secondary veins. The leaves are smaller and, as it is shaded and small, have not been measured. The Eastern Catalpa on Glen Road has many three-pointed leaves and this smaller individual may represent that species. Confirmation will have to await its flowering for floral characters and timing.

North Rosedale Ravine Specimen

The third individual is on the north side of the North Rosedale Ravine, about 50 m east of the Glen Road Bridge, growing in a damp habitat among ash (*Fraxinus americana*), Sugar Maple (*Acer saccharum*) and Manitoba Maple (*A. negundo*). It was about 6-7 years old on the node count in 1991, with increments from 280 to 840 mm long, mean = 560 mm. No flowers were present in 1991.

The larger leaves of the Ravine specimen vary up to 358 mm long over the midrib and tip by 310 mm wide, for a mean value of the Length:Breadth ratios of 1.309 (N = 26; B:L = 0.764). There are no accessory points to these leaves at the ends of the main secondary veins, although convex bulges occur on about 50% of the leaves at these points. A distinct edge in which the main secondary veins form the proximal margin of the leaf for 10-15 mm before a chordate lobe encloses the vein and forms a rounded convex shoulder occurs in about 30% of the leaves.

Discussion

In these characters these young trees agree with those for *C. speciosa* in that blooming is earlier by two weeks than in *C. bignonoides*, in their longer and more tapered leaves (Symonds and Chelminski 1958). However, no distinction on the smell from the crushed leaves could be verified. Further agreement is present in the pubescent undersurface of the leaves, in the broad corolla wings, and in the inconspicuously spotted and notched tube (Scoggan 1979).

C. speciosa is noted as escaped and often naturalised elsewhere. Dodge (1914) reported it as "planted and apparently spreading near Kingsville, Essex Co., in S. Ont., but (1915) not spreading in Lambton Co., somewhat further north" (cited in Scoggan 1979: 1390). *C. speciosa* is only noted as "commonly planted" by Morton and Venn (1990: 73) and Cruise (1969: 100). *C. bignonoides* is, however, noted as "persisting" by both authorities.

The occurrence of these three young trees shows that the Western Catalpa has been able to take advantage of the climatic amelioration in the Toronto area, either due to the "city effect" raising

the minimum temperatures in the area during the past two decades, or due to the more general climatic warming. The setting of viable seeds in about 1984 may have reflected an exceptionally good mast year, as no other seedlings have been located. During the 1950s, when I was a graduate student at the University of Toronto, I attempted to find fertile seeds of *Catalpa*, but found none in more than 50 pods examined over a few years.

These young trees may reflect the effects of a general climatic warming, of the localised climatic amelioration, especially in winter, of the "city effect", or of the immigration into Toronto of the insect that fertilises *Catalpa*. As bees visit *Catalpa* flowers, the latter seems an unlikely possibility. However, the absence of other seedings suggests that an exceptional seed year due to climatic change may be the reason for the presence of these three trees.

Acknowledgments

I thank Jim Hodgins of the Department of Zoology, University of Toronto, for his help in producing this note, and my wife Bee for the photograph used in Figure 1.

Literature Cited

Bonner, F .T., and **D. L. Graney**. 1989. *Catalpa* Scop. Catalpa. Pages 281–283 *in* Seeds of woody plants in the United States. *Edited by* C.S. Schopmeyer. U.S. Department of Agriculture, Forest Service, Agriculture Handbook number 450. 883 pages.

Cruise, J. E. 1969. A floristic study of Norfolk County, Ontario. Transactions of the Royal Canadian Institute 72: 1–116.

Dodge, C. K. 1914. Annotated list of flowering plants and ferns of Point Pelee, Ont., and neighbouring districts. Geological Survey of Canada, Memoir number 54: 1–131.

Dodge, C. K. 1915. The flowering plants, ferns and fern allies growing without cultivation in Lambton County, Ontario. Michigan Academy of Science, Report number 16: 132–200.

Morton, J. K., and **J. M. Venn**. 1990. A checklist of the flora of Ontario: vascular plants. University of Waterloo, Waterloo. 218 pages.

Scoggan, J. J. 1979. The flora of Canada, Volume 4. Museum of Natural Sciences. Pages 1117–1711.

Symonds, W. D., and **S. V. Chelminski**. 1958. The tree identification book. William Morrow, New York. 272 pages.

Received 25 July 1991
Accepted 30 March 1992

Do Estrous Female Gray Squirrels, *Sciurus carolinensis*, Advertise Their Receptivity?

JOHN L. KOPROWSKI[1]

Department of Systematics and Ecology, University of Kansas, Lawrence, Kansas 66045
[1]Present Address: Department of Biology, Willamette University, Salem, Oregon 97301

Koprowski, John L. 1992. Do estrous female Gray Squirrels, *Sciurus carolinensis*, advertise their receptivity? Canadian Field-Naturalist 106(3): 392–394.

Female Eastern Gray Squirrels occasionally vocalize during their single day of estrus. During mating bouts, males aggregate near and pursue females. However, females often avoid overt conflict among males and remain motionless in the tree canopy. If the males did not relocate the female within 15 min, I observed females on five occasions emit a high pitched vocalization which males used to locate the female. The first male to relocate the female mated with her. These observations suggest that estrous females may advertise their location to males.

Key Words: Eastern Gray Squirrel, *Sciurus carolinensis*, vocalizations, reproductive behavior, advertisement.

Vocalizations and advertisement calls by male mammals are common during courtship and mating behavior (Clutton-Brock et al. 1982; Ewer 1968). However, non-aggressive vocalizations of the female that may attract males are reported rarely except in some species of felids and canids (reviewed by Ewer 1968), ungulates (Fraser 1968), pinnipeds (LeBouef 1978) and primates (Galdikas 1981; Harcourt et al. 1981).

In Eastern Gray Squirrels (*Sciurus carolinensis*), as many as 34 males chase a female on her single day of estrus (Goodrum 1961). Males call throughout the chase (Lishak 1982). Olfactory cues likely are important in the location of an estrous female (Thompson 1977); however, after a female avoids the pursuing males, males may use visual cues to find the female (Koprowski 1991). The female frequently avoids the pursuing males, sits motionless in

a tree, and mates with the first male to relocate her (69% of all copulations); females appear to avoid the risk of injury that may result when males attack copulating pairs high in a tree canopy (Koprowski 1993a). Occasionally, males have difficulty relocating a female and may run > 100 m from the female's position. This presents an interesting problem for estrous females: avoid males but be certain to mate. Herein, I report on five instances when males were apparently unable to locate an estrous female after she evaded their pursuit. The female vocalized and the males quickly relocated her.

The study area was a 4.2-ha Black Walnut (*Juglans nigra*)-dominated parkland located on the University of Kansas campus, Lawrence, Douglas County, Kansas. The ground cover was mowed grass; the absence of a shrub stratum and the habituation of squirrels to humans facilitated observations. Since May 1986, I trapped and marked squirrels for identification at a distance; methods are described elsewhere (Koprowski 1991). I focused my observations on the winter breeding season due to the rarity (only six chases) and difficulty of observations because of leaf cover in the May-June breeding period. Each morning prior to dawn from mid-December to mid-February and early May to late June 1987-1990, I traversed the study area in search of males congregating in the vicinity of an estrous female's den. When I detected a mating bout, I followed the activities of males and the estrous female continuously until bout termination.

On five occasions I observed a female call during mating bouts. The vocalizations resembled the 'quaa-moan' call described by Lishak (1984). Males responded immediately to the call by running at and relocating the female.

On 4 June 1987, an estrous female successfully evaded the 12 males involved in her mating chase. The males were unable to relocate the female despite searching for > 20 min; the nearest male was > 50 m from the female when she began to call from a branch located 4 m aboveground. A yearling male was the first to relocate her and copulated with her at 1222 h, only 30 sec after she called.

On 7 January 1988, an estrous female sat 8 m high in a tree at 1242 h while nine males searched within 20 m of her. She gave a short call and a male relocated and mated her at 1245 h.

On 8 January 1988, an estrous female exited the den in which she had holed up at 1100 h while seven males were distracted by chasing each other within the lower canopy of the tree. The female moved undetected into the upper canopy where she sat at 12 m until 1117 h when she called. A male quickly relocated and copulated with her at 1118 h.

On 10 January 1988, during a mating bout involving 16 males, an estrous female evaded the pursuing males. The males searched for the female from 1120 to 1155 h. After one minute of calling by the female, the males relocated her; however, no copulation occurred probably because four males simultaneously relocated the female and fought for proximity to her.

On 5 January 1990 at 0833 h, an estrous female evaded the 17 males that were pursuing her and she remained motionless on a branch 22 m aboveground. She called twice at 0845 h and mated within 30 sec with the first male that relocated her.

No aspect of female calls was unique except that the time since males last approached the female prior to her call was 21.4 ± 8.7 min. I have never observed males fail to approach an estrous female for >15 min during other mating chases ($N = 22$) which suggests that the delay in males relocating females may elicit vocalizations. Females called at 1125 (± 1.6 *SD*) h, 38.5 (± 20.6 *SD*) min after their previous copulation, and 11.5 (± 7.7 *SD*) m aboveground, values well within the normal range of the timing, intercopulatory intervals, and locations of copulations for Eastern Gray Squirrels on this study area (Koprowski 1993a).

Female Eastern Gray Squirrels appear to vocalize to attract males that are unable to relocate the secluded female. Because females are only receptive for several hours on a single day during each breeding season (Thompson 1977), a female must mate in a narrow window of time. Female tree squirrels seek to copulate in seclusion (Koprowski 1993a,b; Wauters et al. 1990); however, the efforts of the female to control the location of copulation carry the potential cost of losing contact with males. The ability of females to manipulate pursuing males and mates, especially in species characterized by dominance polygyny, generally is not acknowledged by behavioral ecologists. Yet, female tree squirrels avoid overt aggression among males and select locations for copulation (Koprowski 1993a,b; Wauters et al. 1990), solicit copulations from subordinate males (Farentinos 1980; Koford 1982), mate with several males (Farentinos 1972; Koford 1982; Koprowski 1993a,b; Wauters et al. 1990), and remove copulatory plugs that are deposited by males in her vagina (Koprowski 1992). Such behaviors likely increase female reproductive success at the expense of the success of individual males. Vocalizations by the female that attract males may be another method by which females maximize their reproductive success.

Acknowledgments

I thank the Theodore Roosevelt Memorial Fund of the American Museum of Natural History, Sigma Xi, The Scientific Research Society, and the Department of Systematics and Ecology at the University of Kansas for financial assistance. The University of Kansas Museum of Natural History graciously provided equipment. Two Summer Fellowships from

The Graduate School at the University of Kansas facilitated field work. I also greatly appreciate the assistance of N. Koprowski, J. Luft, P. Sponholtz, K. Zitta, and K. Zuby in trapping and marking squirrels.

Literature Cited

Clutton-Brock, T. H., F. E. Guinness, and **S. D. Albon**. 1982. Red deer, the behavior and ecology of two sexes. University of Chicago Press, Chicago.

Ewer, R. F. 1968. Ethology of mammals. Logos Press, London. 418 pages.

Farentinos, R. C. 1972. Social dominance and mating activity in the tassel-eared squirrel (*Sciurus aberti ferreus*). Animal Behaviour 20: 316–326.

Farentinos, R. C. 1980. Sexual solicitation of subordinate males by female tassel-eared squirrels (*Sciurus aberti*). Journal of Mammalogy 61: 337–341.

Fraser, A. F. 1968. Reproductive behaviour in ungulates. Academic Press, London. 202 pages.

Galdikas, B. M. F. 1981. Orangutan reproduction in the wild. Pages 281–300 *in* Reproductive biology of the great apes. *Edited by* C. E. Graham, Academic Press, New York. 437 pages.

Goodrum, P. D. 1961. The gray squirrel in Texas. Texas Parks and Wildlife, Austin, Texas. 37 pages.

Harcourt, A. H., K. J. Stewart, and **D. Fossey.** 1981. Gorilla reproduction in the wild. Pages 265–279 *in* Reproductive biology of the great apes. *Edited by* C. E. Graham, Academic Press, New York. 437 pages.

Koford, R. R. 1982. Mating system of a territorial tree squirrel (*Tamiasciurus douglasii*) in California. Journal of Mammalogy 63: 274–283.

Koprowski, J. L. 1991. Mixed-species mating chases of fox squirrels, *Sciurus niger*, and Eastern Gray Squirrels, *S. carolinensis*. Canadian Field-Naturalist 105: 117–118.

Koprowski, J. L. 1992. Removal of copulatory plugs by female tree squirrels. Journal of Mammalogy *in press*.

Koprowski, J. L. 1993a. Alternative reproductive tactics in male eastern gray squirrels: 'making the best of a bad job'. Behavioral Ecology *in press*.

Koprowski, J. L. 1993b. Behavioral tactics, dominance, and copulatory success among male fox squirrels. Ethology Ecology & Evolution *in press*.

Le Boeuf, B. J. 1978. Sex and evolution. Pages 3–33 *in* Sex and behavior. *Edited by* T. E. McGill, D. A. Dewsbury, and B. D. Sachs, Plenum Press, New York. 436 pages.

Lishak, R. S. 1982. Gray squirrel mating calls: a spectrographic and ontogenic analysis. Journal of Mammalogy 63: 661–663.

Lishak, R. S. 1984. Alarm vocalizations of adult gray squirrels. Journal of Mammalogy 65: 681–684.

Thompson, D. C. 1977. Reproductive behaviour of the grey squirrel. Canadian Journal of Zoology 55: 1176–1184.

Wauters, L., A. A. Dhondt, and **R. De Vos.** 1990. Factors affecting male mating success in red squirrels (*Sciurus vulgaris*). Ethology Ecology & Evolution 2: 195–204.

Received 31 July 1991
Accepted 5 March 1992

Efficacy of Three Types of Live Traps for Capturing Weasels, *Mustela* spp.

JERROLD L. BELANT

State University of New York, College of Environmental Science and Forestry, Adirondack Ecological Center, Newcomb, New York 12852

Present address: U.S. Department of Agriculture, Denver Wildlife Research Center, 6100 Columbus Avenue, Sandusky, Ohio 44870

Belant, Jerrold L. 1992. Efficacy of three types of live traps for capturing weasels, *Mustela* spp. Canadian Field-Naturalist 106(3): 394–397.

The efficacy of double-door Havahart, single-door National, and single-door wooden live traps for capturing Long-tailed Weasels (*Mustela frenata*) and Short-tailed Weasels (*M. erminea*) was studied in northern New York during 1991. Overall capture success of all trap types was similar ($P > 0.10$). More Long-tailed Weasels were captured in Havahart traps ($P < 0.05$). Havahart traps sprung without capture were observed more frequently than other trap types ($P < 0.001$). The occurrence of empty, sprung wooden traps was related to rainfall ($P < 0.001$). Trap-related injuries of Long-tailed Weasels captured in Havahart traps included skin abrasions and broken canines.

Key Words: Long-tailed Weasels, *Mustela frenata,* Short-tailed Weasels, *Mustela erminea*, capture rate, live traps, trap-related injuries.

Selection of trap type for use in studying wild animal populations must consider the efficiency of the trap in capturing the species studied (Lacki et al. 1990). Several types of live traps used to capture weasels have been described and evaluated individually (Marsh and Clark 1968; King 1973; King and Edgar 1977). Rust (1968) stated that National traps were less effective than Havahart traps, but provided

no data. Gamble (1980) compared Sherman-type, Tomahawk, and Burt live traps and found Burt traps most suitable for Short-tailed Weasels (*Mustela erminea*) and Long-tailed Weasels (*M. frenata*). My objective was to compare the effectiveness of Havahart, National, and wooden (Patric 1958) live traps for capturing Short-tailed and Long-tailed Weasels.

Study Area and Methods

I conducted the study from 28 April through 18 June 1991 in the central Adirondack Mountains of northern New York (44°00'N, 74°13'W). Elevations range from 460 m to 820 m. Overstory consists of northern hardwoods (72%) mixed hardwood-softwood (18%), and softwood (10%) (Simon 1979). Average annual precipitation was 99 cm, including 253 cm of snowfall (Huntington Wildlife Forest [HWF], unpublished data). Mean January and July temperatures were –9 and 19°C (HWF, unpublished data).

Double-door Havahart (12.5 × 12.5 × 45.5 cm; Model 1, Woodstream Corporation, Lititz, Pennsylvania), single-door National (12.7 × 12.7 × 40.6 cm; National Live Trap Company, Tomahawk, Wisconsin), and single-door wooden live traps (9.0 × 9.5 × 25.5 cm [Patric 1958]) were evaluated. The wooden live traps had an aluminum treadle with an arm extending to an aluminum door. Upon depressing the treadle, the door is released by the treadle arm, closing forward toward the front of the trap.

Traps were positioned at 300-m intervals along a restricted access dirt road system. One trap of each type was used at each location to avoid bias associated with habitat preferences. Each trap at a location was ≤10 m from the other two traps and ≥ 2 m from the road. Traps were placed adjacent to logs, stumps, or rocks and baited with Beaver (*Castor canadensis*) meat. Bait was replaced twice/week and after each capture. Because of their wire-mesh construction, National traps were covered with leaves to provide shelter for captured animals. After capture of an animal, each trap was thoroughly scrubbed or replaced with a similar trap to eliminate scent deposited by the captured animal. Erlinge et al. (1982) and Erlinge and Sandell (1988) have shown that *M. erminea* and *M. nivalis* can be attracted or repelled by the scent of individuals inter- and intra-specifically. Traps were checked daily between 0500 hrs and 0700 hrs Eastern Daylight Savings Time.

All captured weasels were ear-tagged and weighed. I also measured the distance from center of front shoulder to base of tail, as an indication of an individual weasel's ability to be captured in a particular trap type. Captured animals were examined for trap-related injuries including skin abrasions and freshly broken canines. Because animals were generally anesthetized only once during the study (Belant 1992), canine damage was assessed from initial captures only. Recaptured animals were evaluated for skin abrasions if none were observed during previous captures.

Trap success was evaluated using the χ^2 statistic for proportional data (Fleiss 1981). Capture frequencies were adjusted (King 1989) to account for traps unavailable due to capture of other individuals or traps rendered inoperable by larger carnivores (e.g., Raccoon [*Procyon lotor*], Black Bear [*Ursus americanus*]). Tests of trap success were based on all animals captured, including recaptures.

Results and Discussion

Forty-five traps (15 of each type) were set for 36 nights (1620 total trap nights). Overall capture rate was 1.2 weasels/100 adjusted trap nights (Table 1). Capture success for Short-tailed and Long-tailed Weasels reported from other studies ranged from 0.42 to 9.0% (Edgar 1974; Gamble 1980; King 1980; King and McMillan 1982; King 1983). Low capture success during this study is explained partially by clustering three traps at each location as compared to 1 trap/location in other studies. Overall capture success of the three trap types was similar ($\chi^2 = 2.50$, $P > 0.10$). More Long-tailed Weasels were captured in Havahart traps ($\chi^2 = 7.50$, $P < 0.05$). No Long-tailed Weasels were captured in wooden live traps. No female Short-tailed Weasels were captured during the study.

Havahart traps were observed sprung without capture more frequently than the other trap types

TABLE 1. Short-tailed Weasels and Long-tailed Weasels captured using Havahart, National, and wooden live traps, central Adirondack Mountains, New York, from April through June 1991. Number of individuals captured in parentheses.

Trap type	Total Trap Nights	Adjusted Trap Nights	Short-tailed Weasel		Long-tailed Weasel		Combined	
			n captured	% success	*n* captured	% success	*n* captured	% success
Havahart	540	451	2(1)	0.4	5(2)	1.1	7(3)	1.6
National	540	522	7(2)	1.3	1(1)	0.2	8(3)	1.5
Wooden	540	494	3(1)	0.6	0	0.0	3(1)	0.6
Total	1620	1467	12(3)	0.8	6(3)	0.4	18(6)	1.2

($\chi^2 = 691.27$, $P < 0.001$) and wooden traps were sprung without capture proportionally more often than National traps ($\chi^2 = 19.46$, $P < 0.001$). Significantly more wooden traps were sprung without capture when rainfall occurred during the previous 24 hours ($\chi^2 = 31.03$, $P < 0.001$). Rainfall did not affect the number of empty, sprung Havahart ($\chi^2 = 0.19$, $P > 0.50$) or National ($\chi^2 = 1.74$, $P > 0.10$) traps. Intensity of rain did not appear to affect the number of sprung, empty traps for any trap type. I believe the preponderance of empty, sprung Havahart traps may be partially explained by difficulty in adjusting tension against the treadle. On several occasions after setting Havahart traps, the trap had sprung before I had left the area. Filing the door arm flatter where it rests against the treadle arm should reduce this problem.

The distance between the center of the treadle and the bottom door edge of Havahart, National, and wooden live traps was 22.5, 21.0, and 8.0 cm, respectively. The distance from center of front shoulder to base of tail for Long-tailed Weasels was 19.0 cm ($n = 3$) and for Short-tailed Weasels was 10.3 cm ($n = 3$). Thus, the wooden traps used were too small to capture effectively adult Long-tailed Weasels and possibly large Short-tailed Weasels. I believe Long-tailed Weasels that enter the wooden traps are able to back out after springing them. This likely accounted for some sprung, empty wooden traps. Boonstra and Rodd (1982) also attributed sprung, empty traps to larger animals capable of backing out. The difference in distance measured for Havahart and National traps probably did not affect capture success.

The explanation for greater catch of Long-tailed Weasels in Havahart traps is unclear. One possible explanation is the unobstructed view through double-door Havahart traps, as compared to wire mesh on one end of single-door National traps which would partially obstruct the weasels' view. Long-tailed Weasels are more generalized predators whereas Short-tailed Weasels are considered microtine specialists (King 1989). Thus, Long-tailed Weasels may be more wary than Short-tailed Weasels when entering unfamiliar, somewhat restricted entrances.

No injuries were sustained by either species in National or wooden live traps. One Long-tailed Weasel had broken canines and two sustained skin abrasions on the head as a result of capture in Havahart traps. The skin abrasions that occurred are probably a result of trap design. Havahart traps have gravity doors with a wire that falls with the door and locks them in place. However the doors can be opened slightly when an animal pushes against it. Subsequent withdrawal of the weasel's head forces the door against the head, resulting in skin abrasions. Lining the bottom of Havahart doors and entrances with a plastic or rubber coating should reduce these injuries.

Of the three trap types evaluated, National live traps appeared most suitable for capturing Short-tailed Weasels. If properly modified to reduce or eliminate injuries and excessive sprung traps without capture, Havahart traps should be suitable for capturing Long-tailed Weasels. Due to low capture success (small size) and high incidence of empty, sprung traps, I do not recommend the wooden live traps used in this study for capture of either species.

Acknowledgments

I thank J. D. Belant, J. E. Belant, M-K. W. Belant, M. J. Connerton, and C. M. Costello for field assistance. M-K. W. Belant, K. A. Gustafson, and R. W. Sage, Jr. provided comments for manuscript improvement. Adirondack Ecological Center staff provided traps and logistical support for field work. Financial support was provided by the New York State Trappers Association.

Literature Cited

Belant, J. L. 1992. Field immobilization of American Martens (*Martes americana*) and Short-tailed Weasels (*Mustela erminea*). Journal of Wildlife Diseases 28: 662–665.

Boonstra, R., and **F. H. Rodd.** 1982. Another potential bias in the use of the Longworth trap. Journal of Mammalogy 63: 672–675.

Erlinge, S., and **M. Sandell.** 1988. Coexistence of stoat, *Mustela erminea*, and weasel, *M. nivalis*: social dominance, scent communication, and reciprocal distribution. Oikos 43: 242–246.

Erlinge, S., M. Sandell, and **C. Brink.** 1982. Scent marking and its territorial significance in stoats, *Mustela erminea*. Animal Behavior 30: 811–818.

Fleiss, J. L. 1981. Statistical methods for rates and proportions. Second edition. John Wiley and Sons, New York, New York. 321 pages.

Gamble, R. L. 1980. The ecology and distribution of *Mustela frenata longicauda* Bonaparte and its relationships to other *Mustela* spp. in sympatry. M.Sc. thesis, University of Manitoba, Winnipeg. 165 pages.

King, C. M. 1973. A system for trapping and handling live weasels in the field. Journal of Zoology, London 171: 458–464.

King, C. M. 1980. Field experiments on the trapping of stoats (*Mustela erminea*). New Zealand Journal of Zoology 7: 261–266.

King, C. M. 1983. The relationships between beech (*Notofagus* sp.) seedfall and populations of mice (*Mus musculus*), and the demographic and dietary responses of stoats (*Mustela erminea*) in three New Zealand forests. Journal of Animal Ecology 52: 141–166.

King, C. M. 1989. The natural history of weasels and stoats. Cornell University Press, Ithaca, New York. 253 pages.

King, C. M., and **R. L. Edgar.** 1977. Techniques for trapping and tracking stoats (*Mustela erminea*); a review, and a new system. New Zealand Journal of Zoology 4: 193–212.

King, C. M., and **C. D. McMillan.** 1982. Population structure and dispersal of peak-year cohorts of stoats

(*Mustela erminea*) in two New Zealand forests, with especial reference to control. New Zealand Journal of Ecology 5: 59–66.

Lacki, M. J., W. T. Peneston, and **F. D. Vogt.** 1990. A comparison of the efficacy of two types of live traps for capturing Muskrats, *Ondatra zibethicus*. Canadian Field-Naturalist 104: 594–596.

Marsh, R. E., and **W. R. Clark.** 1968. An effective weasel trap. Journal of Mammalogy 49: 157.

Patric, E. F. 1958. Some properties of the small mammal populations of the Huntington Forest. Ph.D. thesis, State University College of Forestry, Syracuse, New York. 202 pages.

Rust, C. C. 1968. Procedure for live trapping weasels. Journal of Mammalogy 49: 318–319.

Simon, S. A. 1979. Vegetation classification and assessment of forest productivity in the Adirondacks. M.Sc. thesis, State University of New York, Syracuse. 169 pages.

Received 10 September 1991
Accepted 7 April 1992

Further Range Extensions of the Crayfish *Orconectes rusticus* in the Lake Superior Basin of Northwestern Ontario

WALTER T. MOMOT

Department of Biology, Lakehead University, Thunder Bay, Ontario P7B 5E1

Momot, Walter T. 1992. Further range extensions of the crayfish *Orconectes rusticus* in the Lake Superior Basin of northwestern Ontario. Canadian Field-Naturalist 106(3): 397–399.

The introducted exotic crayfish, *Orconectes rusticus* has now extended its range to six additional localities in northwestern Ontario, including a first record from Lake Superior. This species could have considerable impact on the littoral zone of low nutrient lakes in the region. Among the possible adverse effects are (1) the reduction or elimination of macrophyte beds, (2) the elimination or reduction of native crayfish species, (3) reduction in the density and species richness of the benthic insect community, (4) direct competition with fish for macrobenthos, (5) elimination of nursery areas for fish and (6) possible predation on the eggs and larvae of substrate spawning fish.

Key Words: Crayfish, *Orconectes rusticus*, Lake Superior, Ontario, range extension, environmental impact.

The crayfish *Orconectes rusticus* is an introduced exotic slowly expanding its range in Ontario. In the eastern portion of northwestern Ontario it is previously recorded only from Pounsford Lake (49°29'N, 88°46'W) located in the north end of the Sibley Peninsula which separates Thunder Bay from Black Bay in Lake Superior (Momot et al. 1988). The only additional published record is from Lake-of-the-Woods at the extreme western edge of Northwestern Ontario (Crocker and Barr 1968). The purpose of this note is to document an expansion of the known range of *O. rusticus* in the Lake Superior Basin.

Survey of Distribution

Since 1988 we have undertaken an extensive fish survey of drainages (ten tertiary watersheds encompassing 155 lakes and 120 streams concentrated in the Great Lakes, St. Lawrence primary watershed division in Ontario) in and near the Lake Superior Basin. Based on this survey we have to date located additional populations of *Orconectes rusticus* in the following water bodies:

1. Lake Lenore (48°03'N, 89°36'W) located southwest of the city of Thunder Bay;
2. Wiswell Lake (48°30'N, 88°45'W) located on the Sibley Peninsula;
3. Pigeon River (48°01'N, 89°42'W) which forms the international boundary between the State of Minnesota and the Province of Ontario; and
4. Pigeon Bay, Lake Superior (48°01'N, 89°32'W). To our knowledge this is the first record of this species for any of the Laurentian Great Lakes proper;
5. Neebing River (48°22'N, 89°15'W) located within the city limits of Thunder Bay;
6. Jackfish River (49°01'N, 88°05'W). A single specimen (27 mm carapace length, ♀) captured with a seine. The stream flows into Nipigon Bay and the species may be in the bay since the specimen was collected near the mouth of the stream below Highway 17.

In five of six localities *Orconectes rusticus* was very abundant. Large numbers ($N \geq 100$) of both juveniles, and adults of both sexes were easily collected. These are well established populations inhabiting these areas over a minimum time frame of at least four years, the length of the life cycle for this species (Momot 1984). Except for Wiswell Lake,

which is connected to Pounsford Lake, with the latter thus serving as a source of entry, the origin of the populations remains unknown but we assume they are angler bait-bucket introductions. In Pigeon Bay, Lenore Lake, and Pigeon River only *O. rusticus* was collected. In Wiswell Lake, *O. rusticus* was the dominant species (60%) with *O. virilis* being the only other species collected. These specimens of *O. rusticus* are now part of the Lakehead University curatorial collection.

The discovery of *Orconectes rusticus* in six disparate localities makes *Orconectes rusticus* a well established species in the Thunder Bay District, found in watersheds located both north and east of Lake Superior, as well as Lake Superior itself. Helgen (1990) notes its presence in the northeastern portion of the State of Minnesota near Ely, but heretofore confined to lakes within the Hudson Bay drainage. The record from the Pigeon River which lies on the international border extends its range further eastward (150 km) in Minnesota and places this species within its Lake Superior drainage. In addition this record extends the range in Ontario by 80 km further west of its previous location in the Lake Superior drainage system. Its presence in Lake Superior will probably result in its dispersion throughout the northern coast of the lake. The likelihood of this event is increased by the presence of many protected shallow water warm bays extending eastward from Pigeon Bay from the international border northeast to Marathon, Ontario. Of particular concern will be its particular impact on this series of warm shallow bays (eg., Jarvis, Pigeon, Cloud, Pine, Sturgeon, Thunder, Black, Nipigon). Most of the productive marshlands located on the north coast of Lake Superior the coldest, deepest, oligotrophic and unproductive of the Laurentian Great Lakes, are contained within these shallow, warm bays. The potential for damage by *O. rusticus* to aquatic vegetation and fisheries should therefore be of great concern (Helgen 1990; Hobbs and Jass 1988). Alarm over the introduction of this species extends as well to its potential impact, in all of northwestern Ontario, on lake vegetation, eggs laid by fish, wild rice beds, and displacement of native crayfish (Helgen 1990).

Specific Impacts

The most serious potential impact from the invasion by *O. rusticus* will be the destruction of beds of aquatic vegetation in unproductive northwestern Ontario shield lakes. This species does reduce macrophyte abundance and species richness in lakes (Magnuson et al., 1975; Lodge and Lorman 1987). The latter showed that in enclosures, at crayfish densities of 19 g-m^2, macrophyte biomass was reduced by 64%. At abundances greater than 140 g-m^2 all macrophytes were eliminated. Destruction results from both consumptive and non-consumptive activity. Even low densities of *O. rusticus* produce a cumulative effect over successive growing seasons (Lodge and Lorman 1987). This effect will be greater for *O. rusticus* than for its congener *O. virilis* because it has a higher metabolic rate (Momot 1984), larger individual size, and often reaches higher population densities (Lodge et al. 1986).

Submerged macrophytes affect and are affected by the aquatic ecosystem. Among many effects they block water movements, cast shade, retard heat transfer, alter sediment and water chemistry, use carbon and oxygen, build sediment, mine nutrients, store and release nutrients, act as a sink or source, provide living space for invertebrates, screen fish movements, enrich plankton communities and support water fowl (Engel 1990).

The impact of *O. rusticus* extends not only to a direct effect on the macrophytes but also to an indirect effect on their associated benthic fauna. In unproductive boreal lakes macrophyte beds are especially important since they serve as: a habitat for invertebrates used as food by both forage and juvenile game fish; a nursery area for juvenile fish; and nesting substrate by such game fish as Northern Pike, *Esox lucius*.

A second major impact from *O. rusticus* may be its competition with forage and juvenile game fish for benthic invertebrates. While large adult crayfish are mainly herbivorous, juveniles are known benthic invertebrate predators (Hanson et al. 1990; Momot 1984, Momot et al. 1978). Increased densities of crayfish reduce macroinvertebrate density, resulting in less food for fish that feed on benthic macroinvertebrates. *O. rusticus* has a higher metabolic rate and presumably an even larger appetite than *O. virilis* (Jones and Momot 1983). It consumes approximately twice as much 0_2 per g wet weight (Momot 1984). A population of *O. rusticus* at the same density as *O. virilis* will therefore probably have at least twice the food intake per day of *O. virilis*.

A third potential impact noted is predation on fish eggs (eg. Magnuson et al. 1975; Savino and Miller 1991). Little is known about this possibility. Horns and Magnuson (1981) showed that crayfish in enclosures consumed trout eggs on rocky and bare substrates but field evidence is lacking. Crayfish are much less active at temperatures below 10°C than other potential egg predators. This would suggest that fish species laying eggs at low temperatures are less affected than substrate spawning species laying eggs at temperatures greater than 10°C. Fish that lay unprotected eggs on rocky or sandy substrates during late spring-summer are expected to be most susceptible — eg., Smallmouth Bass (*Micropterus dolomieui*), Largemouth Bass (*Micropterus salmoides*), Bluegill (*Lepomis macrochirus*) etc.

A final impact would be the elimination of native crayfish by *O. rusticus*. This is the one interaction

most studied by crayfish biologists, especially in Wisconsin (Capelli 1982; Capelli and Munjal 1982); where *Orconectes rusticus* expanded northwards, replacing *Orconectes virilis* and another northern species, *Orconectes propinquus*, in many Wisconsin lakes, with different rates of success in different lakes (Lodge et al. 1986). All three species are opportunistic omnivores with similar habitat requirements (Momot 1984). *O. rusticus* has a large body size and a high innate level of aggression and even though it does not always eradicate other native species, it does have the competitive advantage and often dominates over other species (Capelli and Munjal 1982).

In summary, *O. rusticus* has established itself in Lake Superior and is extending its range into northwestern Ontario. Its impact should be greatest in oligotrophic lakes with limited areas of submerged macrophytes. In lakes lacking those members of the Sunfish family (Centrarchidae) that feed on crayfish it may reach densities that can destroy the submerged macrophytes, reduce or eliminate native crayfish species, indirectly affect fish species that are dependent on macrophytes for a portion of their life cycles, as well as directly compete with fish for benthic food organisms, and perhaps even prey upon their eggs and larvae. It may also cause considerable problems for wild rice producers if it becomes established in wild rice lakes and cultivated ponds (Helgen 1990).

Literature Cited

Capelli, G. 1982 Displacement of northern Wisconsin crayfish by *Orconectes rusticus* (Gerard). Limnology and Oceanography 27: 741–745.

Capelli, G., and **B. L. Munjal.** 1982. Aggressive interactions and resource competition in relation to species displacement among crayfish of the genus *Orconectes*. Journal of Crustacean Biology 2: 486–492.

Capelli, G., and **J. J. Magnuson.** 1983. Morphoedaphic and biogeographic analysis of crayfish distribution in northern Wisconsin. Journal of Crustacean Biology 3(4): 548–564.

Crocker, D. W., and **D. W. Barr.** 1986. Handbook of the crayfishes of Ontario. University of Toronto Press. 158 pages.

Engel, S. 1990. Ecosystem reponses to growth and control of submerged macrophytes: A literature review. Technical Bulletin Number 170, Wisconsin Department of Natural Resources. 20 pages.

Hanson, J. M., P. A. Chambers, and **E. Prepas.** 1990. Selective foraging by the crayfish *Orconectes virilis* and its impact on macroinvertebrates. Freshwater Biology 24: 69–80.

Helgen, J. C. 1990. The distribution of crayfish in Minnesota. Section of Fisheries Investigation Report Number 405. Minnesota Department of Natural Resources. 106 pages.

Hobbs, H. H. III, and **J. P. Jass.** 1988. The crayfishes and shrimp of Wisconsin. Milwaukee Public Museum. 177 pages.

Horns, W. H., and **J. J. Magnuson.** 1981. Crayfish predation on lake trout eggs in trout lake Wisconsin. Rapports et Procés-Verbaux des Réunions, Conseil International pour l'Exploration de la mer 178: 299–303.

Jones, P. D., and **W. T. Momot.** 1983. The bioenergetics of crayfish in two pothole lakes. Freshwater Crayfish 5: 193–209.

Lodge, D. M., A. L. Bekel, and **J. J. Magnuson.** 1985. Lake bottom tyrant. Natural History 94: 32–37.

Lodge, D. M., T. K. Kratz, and **G. M. Capelli.** 1986. Long term dynamics of three crayfish species in Trout Lake, Wisconsin. Canadian Journal of Fisheries and Aquatic Sciences 43(5): 993–998.

Lodge, D. M., and **J. G. Lorman.** 1987. Reductions in submersed macrophyte biomass and species richness by the crayfish, *Orconectes rusticus.* Canadian Journal of Aquatic Science and Fisheries 44(3): 591–597.

Magnuson, J. J., G. M. Capelli, J. G. Lorman, and **R. A. Stein.** 1975. Consideration of crayfish for macrophyte control. Pages 66–74 *in* Water Quality Management Through Biological Control. *Edited by* P. L. Bresonik and J. L. Fox. Symposium Proceedings Report Number ENV. 07-75-1, University of Florida, Gainesville.

Momot, W. T., H. Gowing, and **P. D. Jones.** 1978. The dynamics of crayfish and their role in ecosystems. American Midland Naturalist 99: 10–35.

Momot, W. T. 1984. Crayfish production: A reflection of community energetics. Journal of Crustacean Biology 4: 35–54.

Momot, W. T., C. Hartviksen, and **G. Morgan.** 1988. A range extension for the crayfish *Orconectes rusticus:* Sibley Provincial Park, Northwestern Ontario. Canadian Field-Naturalist 102(3): 547–548.

Savino, J., and **J. E. Miller.** 1991. Crayfish *(Orconectes virilis)* feeding on young lake trout (*Salvelinus namaycush*): Effect of rock size. Journal of Freshwater Ecology 6: 161–170.

Received 30 September 1991
Accepted 5 March 1992

Fourspine Stickleback, *Apeltes quadracus*, from a Freshwater Lake on the Avalon Peninsula of Eastern Newfoundland

CHRISTINE E. CAMPBELL

Department of Biology, Memorial University of Newfoundland, St. John's, Newfoundland A1B 3X9
Present address: Department of Zoology, University of Adelaide, G.P.O. Box 498, Adelaide, South Australia 5001, Australia

Campbell, Christine E. 1992. Fourspine Stickleback, *Apeltes quadracus*, from a freshwater lake on the Avalon Peninsula of eastern Newfoundland. Canadian Field-Naturalist 106(3): 400–402.

Apeltes quadracus, the Fourspine Stickleback, was collected from Paddys Pond, a freshwater lake on the Avalon Peninsula of Newfoundland, thus extending the species' known range. This species primarily inhabits marine and brackish waters on the eastern coast of North America. The number of *A. quadracus* collected was much lower than the collected number of Threespine Stickleback, *Gasterosteus aculeatus*. The presence of Fourspine Stickleback in Paddys Pond might be a result of an inadvertent introduction. *A. quadracus* was not sampled in previous surveys of Avalon Peninsula lakes.

Key Words: *Apeltes quadracus*, Fourspine Stickleback, freshwater lakes, Avalon Peninsula, eastern Newfoundland, range extension, introduction.

Apeltes quadracus (Mitchill), the Fourspine Stickleback, is primarily known as an inhabitant of marine or brackish waters and is distributed along the eastern coast of North America from the Gulf of St. Lawrence south to Virginia (Scott and Scott 1988). In insular Newfoundland, *A. quadracus* has been collected in brackish and estuarine waters along the west coast of the island (Scott and Crossman 1964; Van Vliet 1970) and from the western portion of the Avalon Peninsula, along Placentia Bay (Scott and Crossman 1964; Garside 1970; Lewis 1978) and St. Mary's Bay (Hanek and Threlfall 1970). This species has also been noted to occur occasionally in freshwater lakes in western Newfoundland; collections of *A. quadracus* have been made from a few freshwater lakes on the northwestern coast of the island (Dadswell 1972) and on the tip of the Great Northern Peninsula (Rombough et al. 1981). Fresh water collections of this species have been made in New Brunswick (Scott and Crossman 1959), Nova Scotia (Scott and Crossman 1964) and Pennsylvania (Nelson 1968) as well. I report here on the collection of *A. quadracus* from a freshwater lake on the eastern portion of the Avalon Peninsula, near the city of St. John's, which extends the known range of this species (Scott and Scott 1988) in Newfoundland.

Collections of Fourspine Stickleback were made in 1987 in conjunction with a study of the distribution of *Gasterosteus aculeatus* Linnaeus, the Threespine Stickleback, in 15 Avalon lakes (Campbell and Knoechel 1990). One of the lakes, Paddys Pond, was also sampled in the spring of 1991. Fish were collected using liver-baited minnow traps that were laid out overnight in two trap strings along the bottom of the lakes, with sampling periods in the spring (mid-May to mid-June) and late summer (mid-August to early September). The trap strings were laid out at opposite ends of each lake and stretched from shore towards the deepest part of the lake, except in 1991 when the traps were all laid out close to shore. Sticklebacks trapped overnight were counted and released. Voucher specimens of *A. quadracus* and *G. aculeatus* have been deposited at the Newfoundland Museum in St. John's, Newfoundland (Newfoundland Museum Catalogue Number PI-43).

Fourspine Sticklebacks were found in only one of the 15 surveyed Avalon lakes (Paddys Pond), while Threespine Sticklebacks were found in Paddys Pond plus 10 other Avalon lakes (Figure 1, *see also* Campbell and Knoechel 1990). Paddys Pond is located 8 km inland from Conception Bay in the watershed of the Topsail-Manuels Rivers system, with obstructions at both river inlet and outlet (Wiseman 1972). The lake is shallow and of low specific conductivity (Table 1), typical of lakes on the Avalon Peninsula (Wiseman 1973; Wiseman and Whelan 1974; Knoechel and Campbell 1988). The number of Fourspine Sticklebacks collected in Paddys Pond was very low compared to the number of Threespine Sticklebacks collected in both 1987 and 1991 (Table 2).

Both the sparse occurrence of *A. quadracus* in the Avalon lakes that were sampled, and the low abundance of this stickleback in the lake in which it was found, are in accordance with results from other surveys of freshwater lakes in Newfoundland. Previous surveys of fish species in 27 Avalon lakes (Paddys Pond, plus 26 other lakes not covered in this present study) did not find *A. quadracus*, while *G. aculeatus* was noted to be quite common (Wiseman 1972, 1973; Wiseman and Whelan 1974). Approximately 22 500 and 93 000 Threespine Sticklebacks were planted in Paddys Pond in 1971 and 1972, respectively (Wiseman 1972) in order to increase the original population of Threespine Sticklebacks to serve as

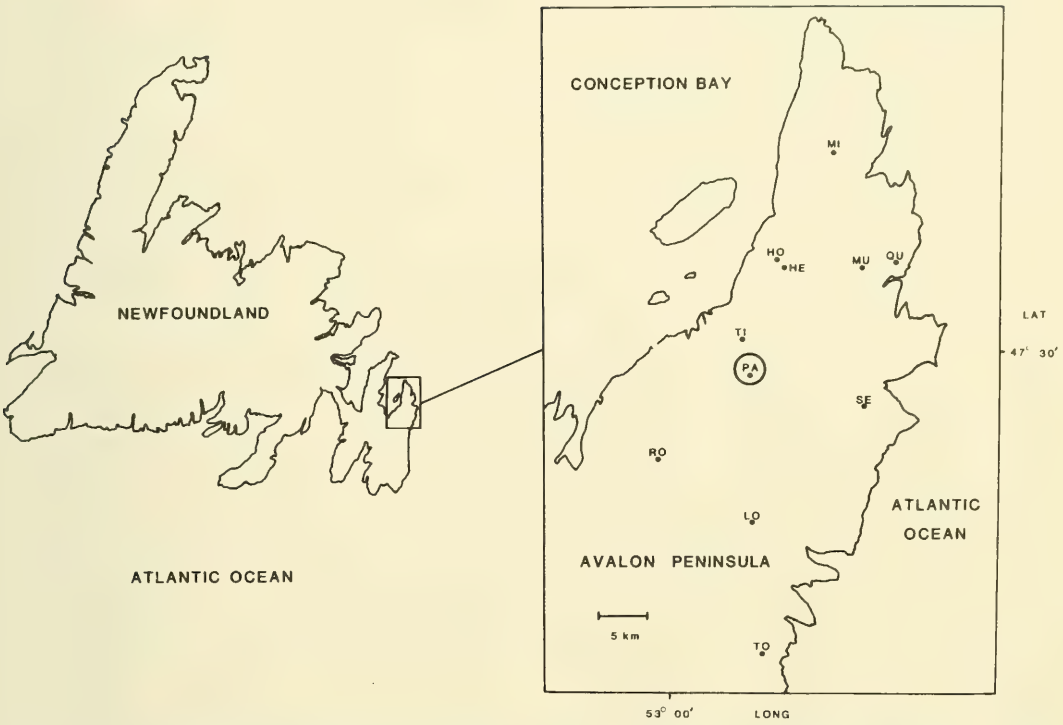


FIGURE 1. The 11 Avalon Peninsula lakes from which Fourspine and Threespine sticklebacks were collected in 1987: *A. quadracus* from Paddys Pond (PA; circled) only, *G. aculeatus* from all 11 ponds (Paddys Pond, HE = Healeys Pond, HO = Hogans Pond, LO = Long Pond, MI = Middle Three Island Pond, MU = M.U.N. (Memorial University of Newfoundland) Long Pond, QU = Quidi Vidi Lake, RO = Round Pond, SE = Second Pond, TI = Three Island Pond, TO = Tors Cove Pond).

forage fish for the resident salmonids *Salvelinus fontinalis* (Mitchill) (Brook Trout) and landlocked *Salmo salar* Linnaeus (Atlantic Salmon); Fourspine Sticklebacks might have been inadvertently introduced at this time. Other fish species found in the Avalon lakes were *Anguilla rostrata* (LeSueur) (American Eel), *Pungitius pungitius* (Linnaeus) (Ninespine Stickleback), the introduced *Salmo trutta* Linnaeus (Brown Trout), landlocked *Osmerus mordax* (Mitchill) (Rainbow Smelt) and *Salvelinus alpinus* (Linnaeus) (Arctic Char) (Wiseman 1973; Wiseman and Whelan 1974).

Lewis (1978) also sampled a number of freshwater and marine sites on the Avalon Peninsula and found *A. quadracus* only in a brackish pool with connections to the sea near Pt. Verde, Placentia Bay. Of the 1692 sticklebacks collected in this pool, 15% were *A. quadracus* and the remainder were *G. aculeatus*. Dadswell (1972) sampled seven lakes in the Bonne Bay region of western Newfoundland and found *A. quadracus* in only one lake with the number of fish caught unreported. The lake had a total water hardness of 12 ppm (Dadswell 1972). Of the three lakes on Newfoundland's Great Northern Peninsula that were sampled by Rombough et al. (1981), *A. quadracus* was found only in one lake; this lake had a specific conductivity of 52 μS/cm. Only one specimen was collected, leading Rombough et al. to conclude that the Fourspine Stickleback had probably strayed from a nearby salt marsh (the lake was within 1 km of the ocean) located by the lake outlet. *G. aculeatus*, *P. pungitius*, *S. salar*, *S. fontinalis*, *S. alpinus*, *O. mordax*, and *A. rostrata* were also collected from the lakes surveyed by Dadswell (1972) and Rombough et al. (1981).

TABLE 1. Some physical and chemical characteristics of Paddys Pond, Newfoundland (data from Knoechel and Campbell 1988). Specific conductivity and pH refer to mean values over the open-water season.

Surface area (ha)	213
Mean depth (m)	3.2
Maximum depth (m)	11.0
Specific conductivity (μS/cm)	40
pH	6.0

In marine and brackish water, male Fourspine Stickleback have a one year life-span, while females may survive the second winter to spawn the following spring (Scott and Scott 1988). *A. quadracus* is

TABLE 2. Number of *Apeltes quadracus* (Fourspine Stickleback) and *Gasterosteus aculeatus* (Threespine Stickleback) collected from Paddys Pond during spring (June 15) and late summer (August 22) 1987, and spring (June 19) 1991. Numbers in brackets refer to the number of minnow traps in which each stickleback species was found (numerator) over the total number of traps set out in the lake.

Species	Spring 1987	Summer 1987	Spring 1991
A. quadracus	6 (5/13 traps)	6 (5/14 traps)	1 (1/4 traps)
G. aculeatus	525 (9/13 traps)	291 (10/14 traps)	205 (4/4 traps)

also physiologically able to reproduce in fresh water. Nelson (1968) reported on a large, well-established population of *A. quadracus* from Pennsylvania; this landlocked population was thought to have descended from an introduction in the 1920s. Given the possibility that Fourspine Sticklebacks were introduced into Paddys Pond in 1971 and 1972, with specimens still collected some years later in 1987 and 1991, it would seem that a small self-sustaining population might exist in this freshwater Newfoundland lake. Determining the ecological importance of Fourspine Stickleback in Newfoundland lakes, either as a forage fish species for salmonids or as a predator of invertebrates, requires further investigation.

Acknowledgments

This work was supported by a Memorial University of Newfoundland graduate fellowship to C. E. Campbell and a Natural Sciences and Engineering Research Council of Canada operating grant to Roy Knoechel.

Literature Cited

Campbell, C. E., and **R. Knoechel**. 1990. Distribution of vertebrate and invertebrate planktivores in Newfoundland lakes with evidence of predator-prey and competitive interactions. Canadian Journal of Zoology 68: 1559–1567.

Dadswell, M. J. 1972. New records of freshwater fishes from the northwest coast of insular Newfoundland. Canadian Field-Naturalist 86: 289–290.

Garside, E. T. 1970. New samples of the piscifauna of insular Newfoundland. Canadian Field-Naturalist 84: 385–386.

Hanek, G., and **W. Threlfall**. 1970. Helminth parasites of the fourspine stickleback (*Apeltes quadracus* (Mitchill)) in Newfoundland. Canadian Journal of Zoology 48: 404–406.

Knoechel, R., and **C. E. Campbell**. 1988. Physical, chemical, watershed and plankton characteristics of lakes on the Avalon Peninsula, Newfoundland, Canada: a multivariate analysis of interrelationships. Verhandlungen Internationale Vereinigung für Theoretische and Angewandte Limnologie 23: 282–296.

Lewis, D. B. 1978. The distribution of sticklebacks (Gasterosteidae) on the Avalon Peninsula of Newfoundland, and the meristic and mensural variations of some selected populations. B.Sc. Honours thesis, Memorial University of Newfoundland, St. John's, Newfoundland. 49 pages.

Nelson, J. S. 1968. Salinity tolerance of brook sticklebacks, *Culaea inconstans*, freshwater ninespine sticklebacks, *Pungitius pungitius*, and freshwater fourspine sticklebacks, *Apeltes quadracus*. Canadian Journal of Zoology 46: 663–667.

Rombough, P. J., **S. E. Barbour**, and **J. J. Kerekes**. 1981. Freshwater fishes from northern Newfoundland. Canadian Field-Naturalist 95: 359–361.

Scott, W. B., and **E. J. Crossman.** 1959. The freshwater fishes of New Brunswick: a checklist with distributional notes. Contribution to the Royal Ontario Museum, Division of Zoology and Paleantology. 51. 37 pages.

Scott, W. B., and **E. J. Crossman**. 1964. Fishes occurring in the fresh waters of insular Newfoundland. Department of Fisheries, Canada, Queen's Printer. 124 pages.

Scott, W. B., and **M. G. Scott.** 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219. 719 pages.

Van Vliet, W. H. 1970. Shore and freshwater fish collections from Newfoundland. National Museum of Canada, Publications in Zoology 3: 1–30.

Wiseman, R. J. 1972. The limnology, ecology and sport fishery of Paddys Pond: a heavily fished lake near metropolitan St. John's, Newfoundland. Progress Report Number 84, Fisheries Service, Resource Development Branch, Environment Canada, Newfoundland Region, St. John's. 157 pages.

Wiseman, R. J. 1973. The limnology and sport fish populations of selected Avalon Peninsula lakes. Progress Report Number 100, Fisheries Service, Resource Development Branch, Environment Canada, Newfoundland Region, St. John's. 167 pages.

Wiseman, R. J., and **W. G. Whelan**. 1974. The limnology and sport fish populations of 10 Avalon Peninsula lakes. Data Report Series Number New/D-74-7, Fisheries and Marine Service, Resource Development Branch, Environment Canada, Newfoundland Region, St. John's. 108 pages.

Received 3 July 1991
Accepted 17 March 1992

Prey of the Sea Anemone *Stomphia didemon* (Anthozoa: Actiniaria) on the West Coast of Canada

JAMES E. DALBY, JR.

Department of Zoology, University of Alberta, Edmonton, Alberta T6G 2E9
Present address: Zoology Department, Melbourne University, Parkville, Victoria 3052, Australia

Dalby, James E., Jr. 1992. Prey of the sea anemone *Stomphia didemon* (Anthozoa: Actiniaria) on the west coast of Canada. Canadian Field-Naturalist 106(3): 403–404.

Eighty-two *Stomphia didemon* from Barkley Sound, British Columbia were held in laboratory until a mucus-wraped food bolus was extruded. Gut contents were mainly small crustaceans and scallops in the 73% that contained food.

Key Words: Sea anemone, *Stomphia didemon*, Anthozoa, Actiniaria, food, British Columbia.

In the Pacific northwest, *Stomphia* spp. are unique among actinians in their ability to detach from the substratum and swim. This unusual behavior has been studied repeatedly, especially in terms of its physiology, and to a lesser degree in terms of its ecology (references in Dalby et al. 1988; Elliott et al. 1989). Despite all of the attention given to these sea anemones, most aspects of their natural history have somehow been overlooked. Below I provide the first data on prey of *Stomphia didemon*.

Materials and Methods

S. didemon were collected in Barkley Sound, Vancouver Island, British Columbia, Canada (125°W, 49°N) at San Jose Islets (52 specimens), Tyler Rock (15), Chup Point (10), Dixon Island (2), Effingham Inlet (1), Hosie Islets (1) and Rowland Islet (1). Anemones (8–14 cm pedal disc diameter) were collected from July to November 1984, at depths of 15–25 m using scuba.

After manually removing debris from specimens, I placed each individual in a glass bowl containing sea water in the lab. Over a 24 h period, each anemone extruded a mucus-wrapped food bolus. The food boluses were examined under a dissecting microscope within 24 h.

Results and Discussion

The gut contents of *S. didemon* were composed mainly of small crustaceans and scallops; 37% of anemones had empty coelenterons (Table 1). Many potential prey taxa were not found in the coelenterons of *S. didemon* (e.g. scyphozoans, turbellarians) possibly because they lacked any hard parts and had been completely digested by the time the food boluses were examined.

The largest prey was the scallop *Chlamys hastata*. Empty scallop shells were frequently seen around the pedal discs of *S. didemon* in nature. Other predators of *C. hastata* include asteroids (Mauzey et al. 1968; Bloom 1975).

Experiments suggest that asteroid predators contribute to the scarcity of *S. didemon* at shallow depths in Barkley Sound (Dalby et al. 1988). Perhaps prey abundance also affects the vertical distribution of this anemone; in my hundreds of dives in Barkley Sound, I have never seen *C. hastata* at shallow depths (< 15 m).

As far as I know, there are no other published data on prey of actinians on the west coast of Canada, and in all of Canada, there are published data on prey of only one other actinian species: *Nematostella vectensis* in Nova Scotia (Frank and Bleakney 1978).

Also to my knowledge, there are published records on prey of only two species of Actinostolidae worldwide: *Antholoba achates* in Chile (Sebens and Paine 1978) and *Sicyonis tuberculata* in western Europe (Lampitt and Paterson 1987). Neither one of these accounts is sufficiently detailed for meaningful comparison with the diet of *S. didemon*.

TABLE 1. Gut contents of 82 specimens of *Stomphia didemon*. (* = more than 200 items).

Taxa	Item length (mm)	# prey items	% anemones with prey
Crustacea			**84**
Amphipoda	3–6	12	11
Copepoda	2	1	1
Megalopa	5	2	2
Cyprids	0.3–1	*	16
Parts of small crustaceans	0.5–2	*	54
Mollusca			**14**
Scallop (*Chlamys hastata*) shells	0.5–30	20	12
Clam shells	2	1	1
Snail shells	1.1	1	1
Miscellaneous			**7**
Polychaetes	8,20	2	2
Bryozoan colony	2	1	1
Algae	0.5–5	4	4
Nothing	–	–	**37**

Acknowledgments

I thank J. Elliott and D. Westlake for scuba help; Bamfield Marine Station, Bamfield and the late Dr. D. Ross for providing lab space and equipment; and D. Fautin for reviewing the manuscript. This work was done as a side-project during a Natural Science and Engineering Research Council of Canada undergraduate summer research award.

Literature Cited

Bloom, S. A. 1975. The motile escape response of a sessile prey: a sponge-scallop mutualism. Journal of Experimental Marine Biology and Ecology 17: 311–321.

Dalby, J. E. Jr., J. K. Elliott, and **D. M. Ross.** 1988. The swim response of the actinian *Stomphia didemon* to certain asteroids: distributional and phylogenetic implications. Canadian Journal of Zoology 66: 2484–2491.

Elliott, J. K., D. M. Ross, C. Pathirana, S. Miao, R. J. Andersen, P. Singer, W. C. M. C. Kokke, and **W. A. Ayer.** 1989. Induction of swimming in *Stomphia* (Anthozoa: Actiniaria) by imbricatine, a metabolite of the asteroid *Dermasterias imbricata*. Biological Bulletin 176: 73–78.

Frank, P. G., and **J. S. Bleakney.** 1978. Asexual reproduction, diet, and anomalies of the anemone *Nematostella vectensis* in Nova Scotia. Canadian Field-Naturalist 92: 259–263.

Lampitt, R. S., and **G. L. J. Paterson.** 1987. The feeding behavior of an abyssal sea anemone from in situ time lapse photographs and trawl samples. Oceanologica Acta 10: 455–461.

Mauzey, K. P., C. Birkeland, and **P. K. Dayton.** 1968. Feeding behavior of asteroids and escape responses of their prey in the Puget Sound region. Ecology 49: 603–619.

Sebens, K. P., and **R. T. Paine.** 1978. Biogeography of anthozoans along the west coast of South America: habitat, disturbance and prey availability. New Zealand Department of Scientific and Industrial Research Information Series 137: 219–237.

Received 4 September 1990
Accepted 4 June 1992

First Confirmed Canadian Sight Record of Bendire's Thrasher, *Toxostoma bendirei*

ALEXANDER MILLS

40 Theresa Street, Barrie, Ontario L4M 1J4

Mills, Alexander. 1992. First confirmed Canadian sight record of Bendire's Thrasher, *Toxostoma bendirei*. Canadian Field-Naturalist 106(3): 404–405.

A Bendire's Thrasher, *Toxostoma bendirei*, was observed 28–30 May, 1988 in Jasper National Park. Diagnostic photographs were taken, making this the first confirmed record for Canada.

Key Words: Bendire's Thrasher, *Toxostoma bendirei*, first record, Canada.

The Bendire's Thrasher (*Toxostoma bendirei*) breeds in open farmland, grassland, and scrubby desert from central Utah south to NW Mexico and from SE California east to central New Mexico (A.O.U. 1983). Of the five thrashers confined in North America to the American southwest, it is the only one that migrates regularly.

The status of the Bendire's Thrasher in Canada to now has been hypothetical, based on two sight records by competent observers (Godfrey 1986). On 27 May 1972, J. B. and M. F. Gollop carefully studied a bird east of Dundurn, Saskatchewan (Houston 1972). On 14 May 1974, nine observers identified one at Grand Beach, Manitoba (Houston and Shadick 1974). In neither case were substantiating photographs or specimens taken.

On 28 May 1988, Roy Richards was watching birds at Buffalo Prairie (or Prairie de la Vache, UTM 323494) in Jasper National Park, Alberta. He discovered a bird he identified tentatively as a Bendire's Thrasher. He rediscovered the bird on 29 May, and on 30 May, he, Kevin Van Tighem, Peter Goddard, F. Mogensen, and I found and studied the bird. I made some field notes and took several photographs. It was looked for again into early June, but was not seen again beyond 30 May.

The bird was frequenting a dry grassy valley surrounded by Lodgepole Pine (*Pinus contorta*) forest. Through the valley ran a small creek along which were scattered scrubby willows (*Salix* sp.) and various shrubs. The bird was consistently found near the creek, perching in and around the tangled vegetation. On the morning of 30 May, it was associating with American Robins (*Turdus migratorius*), but later in the day it was alone.

The bird was similar to a Gray Catbird (*Dumetella*

FIGURE 1. Bendire's Thrasher, *Toxostoma bendirei*, photographed at Buffalo Prairie, Jasper National Park, Alberta, 30 May 1988 by A. Mills.

carolinensis) in bulk and shape, being fairly slim with a relatively long tail. The overall colouration was a buffy gray-brown, somewhat darker dorsally. There were indistinct grayish markings on the breast, giving it a dirty appearance. The wings showed no wing bars or markings, either at rest or in flight. The iris was distinctly yellow. The culmen was distinctly curved but the lower mandible was not, giving the beak a virtually straight aspect. No observer heard the bird make any vocalizations.

Three colour slides taken with a 400 mm Canon 4.5 lens were sent to the Canadian Museum of Nature in Ottawa and were reviewed and accepted as diagnostic by Dr. W. Earl Godfrey. These slides are on file in the Museum and two are reproduced here. (Cover and Figure 1).

The combination of straight beak, lemon yellow eye, lack of wing bars, and the markings on the breast clearly indicate it was a Bendire's Thrasher. The indistinct nature of the breast markings and the absence of any cinnamon colouring suggest it was probably an adult (Bent 1948), although these features do not show in the photographs.

Separation of the Bendire's Thrasher from the *palmeri* race of the Curve-billed Thrasher, *Toxostoma curvirostre*, is not always easy (Kaufman and Bowers 1990; W. Earl Godfrey, personal comment). The latter can have indistinct breast markings and yellow eyes, and juveniles can have short straight beaks. However, as revealed in the photographs, the length of the straight beak of the Jasper bird does provide diagnostic evidence; having attained that length without showing any tendency to decurve indicates it was not a Curve-billed Thrasher.

No unusual weather patterns immediately preceeded the sighting. The spring of 1988 was extremely dry on the prairies, however, and more than usual numbers of prairie species were found east and west of their normal summer ranges (personal observation). Whether this sighting was part of this phenomenon or whether it merely constituted an individual that overshot a migration destination is uncertain.

Acknowledgments

I am particularly grateful to Dr W. Earl Godfrey who made helpful comments in the preparation of and review of this note.

Literature Cited

American Ornithologists' Union. 1983. Check-list of North American Birds, Sixth Edition. American Ornithologists' Union, Washington, D.C. 877 pages.

Bent, A. C. 1948. Life histories of North American nuthatches, wrens, thrashers, and their allies. Smithsonian Institution. United States National Museum Bulletin 195.

Godfrey, W. E. 1986. The Birds of Canada, Revised Edition. National Museum of Natural Sciences, Ottawa. 595 pages.

Houston, C. S. 1972. Northern Great Plains region. American Birds 26: 774–777.

Houston, C. S., and **S. J. Shadick.** 1974. Northern Great Plains region. American Birds 28: 814–817.

Kaufman, K., and **R. Bowers.** 1990. Curve-billed Thrasher and Bendire's Thrasher. American Birds 44: 359–362.

Received 12 July 1991
Acdepted 2 March 1992

News and Comment

George Hazen McGee, 1909-1991

George McGee, Honorary Member of the *The Ottawa Field-Naturalists' Club* and active Ottawa field-naturalist, died 1 December 1991 at age 82. A tribute will appear in a future issue of *The Canadian Field-Naturalist.*

Louise de Kirkland Lawrence, 1894-1992

Honorary Member of *The Ottawa Field-Naturalists' Club* and acclaimed naturalist-author, Louise de Kirkland Lawrence died 27 April 1992 at age 98. A tribute will appear in a future issue of *The Canadian Field-Naturalist.*

Some External Awards to Members of *The Ottawa Field-Naturalists' Club* and Contributors to *The Canadian Field-Naturalist*

Stewart D. MacDonald, honorary member of *The Ottawa Field-Naturalist Club*, former Curator of the Ethology Section, and Curator Emeritus since 1989, with the National Museum of Canada (now Canadian Museum of Nature) was awarded the 1992 Massey Medal of *The Royal Canadian Geographic Society*, the highest Canadian award for achievements in exploration, development, or description of this country's geography. It was presented by the Governor-General Ramon John Hnatyshyn at Rideau Hall.

This award was in tribute for a lifetime of High Arctic research which began in 1949, and, particularly, for efforts in initiating an inland High Arctic research station at Polar Bear Pass, Bathurst Island, in 1968. He has been an particularly effective spokesman for the uniqueness and fragility of the arctic habitat, through papers both scientific and popular, lectures, work with the CBC on TV specials and exhibits at the Canadian Museum of Nature. In 1975, he also helped set up the Seymour Island Bird Sanctuary. In 1986, his efforts contributed to Polar Bear Pass, an area of 2,624 kilometres, being set aside as the first National Wildlife Area in the Arctic. A description of this area and Stu's role in the research there by B. Theresa Aniskowicz appeared in *Canadian Geographic* 108(1): 47-53 (1988) and a tribute when the award was announced "1992 Massey Medalist: Scientist with the soul of an artist", also by B.T. Aniskowicz, appeared in *Canadian Geographic* 112(3): 16-18, May-June 1992.

George W. Argus was awarded a 1991 *Lawson Medal* by *The Canadian Botanical Association* for outstanding scientific achievement in a single area in recognition of his leadership role in the Rare and Endangered Plant Project of the Canadian Museum of Nature. This project, begun in 1973, has resulted in provincial and territorial lists published by the National Museum of Canada (later The Canadian Museum of Nature), and related publications involving more than 100 authors. The publication of the comprehensive *Rare Vascular Plants in Canada* (G. W. Argus and K. M. Pryer. 1990. Canadian Museum of Nature. 191 pages plus maps) has placed this country in a leading position internationally among nations with comprehensive documentation of their rare botanical resources. A testament to Dr. Argus's contribution appears in the *Canadian Botanical Association Bulletin* October 1991, pages 64-65.

Donald M. Britton was the recipient of a 1991 Lawson Medal from the Canadian Botanical Association for outstanding scientific achievement over the period of a career involving many separate contributions. Dr. Britton spent a year with the Department of Plant Sciences at the University of Alberta and five years at the University of Maryland before joining the University of Guelph in 1958. He became a Professor in the Department of Botany and Genetics there in 1971. Dr. Britton is internationally recognized for his contributions to the study of the evolution of ferns and has pioneered the use of cytogenetic techniques and scanning electron microscopy in the fern systematics. He has coauthored *Ferns and Fern Allies of Canada* (W. J. Cody and D. M. Britton. 1989. Agriculture Canada, Research Branch Publication 1829/E. 430 pages). A fuller account of Dr. Britton's contributions appears in The Canadian Botanical Association Bulletin October 1991, pages 66-67.

Francis R. Cook was the recipient of the first *Distinguished Canadian Herpetologist* award by *The Canadian Association of Herpetologists* at their annual meeting in June 1991. This award, created to honour researchers who have greatly contributed to herpetology in Canada, confers honorary life membership in the Association formed in 1986 and will be given not oftener than every five years. It was presented in recognition of his involvement in building the largest herpetology research collection in Canada at the National Museum of Canada (now Canadian Museum of Nature) as Museum Labourer, Summer Student, and Technical Officer (1954, 1956-1959) and as Curator of the Herpetology Section for 32 years (1960-1991), for scientific and popular publications, and for his personal involvement with Canadian herpetology said to "inspire ever increasing numbers of young herpetologists." (*Canadian Association of Herpetologists Bulletin* 5(2): 7, October 1991).

Book Reviews

ZOOLOGY

ZOO The Modern Ark

By Jake Page. Photographer Franz Maier. Facts on File, New York, 191 pp., illus. U.S. $35. No Canadian Rights.

"Zoological gardens, from ancient China and from the time of the Aztecs, have been with and are with us still. Zoos are not out of date. Indeed, they are becoming of greater importance with each passing year..." writes Gerald Durrell in the Preface to this attractive book. Zoos have drastically changed from the first animal park that existed in the ancient Sumerian City of Ur in 2300 B.C. and since the establishment of the first modern zoo in Regent's Park in Britain in 1826.

One major influence in zoo management was initiated by Carl Hagenbeck in 1907. Hagenbeck's idea was to exhibit animals in more naturalistic settings and if possible at eye-level to the viewers. This concept has had lasting impact and is evident in present-day zoological gardens. Another turning point in zoo management arose after an article appeared in Science magazine by Katherine Ralls revealing the shocking correlation of juvenile mortality to inbreeding. Ralls' article and continued studies on this subject had a remarkable impact on zoos around the world.

In *ZOO The Modern Ark*, author Jake Page does an excellent job in examining the improvements, achievements, and role of zoos in today's society. Zoos no longer house animals solely for viewing pleasure but have recently been recognized in the conservation field as sanctuaries for endangered species, for successful re-introduction of animals into the wild, and by providing homes to species threatened by loss of habitat.

The author moves from one fascinating topic to another. Page examines animals throughout the world through various perspectives, one being statistics. The development of such programs as the International Species Inventory Systems (ISIS), which maintains lists of individual animals throughout world zoos, births, and acquisitions from the wild, aids researchers and zoo management in careful monitoring of zoo populations, genetic drift, and the degree of inbreeding. ISIS assists in the co-operative effort of all zoos to exchange animals for breeding purposes. Page thoroughly discusses and yet simplifies complex subjects such as genetics by using effective analogies easily comprehended by the lay readers.

Over six hundred zoos exist in the world and the author highlights ten of the finest, including the Metro Toronto Zoo. The Toronto Zoo is one of the few that group animals by zoo-geographical area. It has gained recognition for its involvement in species-survival programs and captive breeding, and houses about fifty Endangered Species. The book is sumptuously illustrated throughout. The Appendices listing pertinent addresses of zoos, descriptions, and supporting agencies is informative.

"Zoos, along with aquariums and game parks, are one of the greatest potential tools available to society to alter the attitudes of a significant proportion of mankind, to create a deep-seated awareness that we are not rightfully the overlords of this planet but share it with a vast and beautiful array of life-forms, each with intrinsic merit" concludes Page. *Zoo, the Modern Ark* provides stimulating reading and brilliant insight into the workings, objectives and challenges of today's zoos.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario K0A 2W0

The Magpies: The Ecology and Behaviour of Black-billed and Yellow-billed Magpies

By Tim Birkhead. 1991. T & AD Poyser, London. (Distributed in North America by Academic Press, Harcourt Brace Jovanovich, San Diego). 272 pp., illus., U.S. $ 39.95.

Few bird species can boast of a east-west distribution as widespread as that of the Black-billed Magpie, *Pica pica*. Except for an interruption in Eastern North America (from the Great Lakes and the Mississippi River to the East Coast), the distribution range of the Black-billed Magpie forms a belt around the world at temperate latitudes. The magpie's ubiquitousness, combined with its striking appearance and bold behaviour (where non-persecuted), may explain why this bird figures prominently in the folklore of so many countries. This place in folklore is not always a flattering one however, as many people have learned to dislike the magpie and

blame it for killing songbirds, attacking injured wildlife and livestock, and even stealing jewellery.

Given this long-standing "popularity", it is somewhat surprising that the scientific study of magpies did not begin in earnest until about a decade ago. Since then however, research has proceeded at a steady pace in both North America and Europe. The time had come for a synthesis, and Tim Birkhead's book represents a timely arrival. This interesting volume reviews what is known about the ecology and behaviour of the Black-billed Magpie and its California-restricted sister species, the Yellow-billed Magpie, *Pica nuttalli*.

The contents include 12 chapters and 9 appendices. The first chapter is an introduction to the general biology of the two species. A section on the methodology of magpie study, based on the author's own experience with a magpie population in Sheffield, U.K., anchors the text in practicality. Another nice feature is a table listing the main sites of study in the world and the workers involved.

The next three chapters deal with social behaviour. Chapter 2 is concerned with nest spacing and territorial behaviour. Chapter 3 addresses the social behaviour of breeding magpies and it covers dispersal, pair formation, pair maintenance, and mate guarding. There are also sections on roosting and mobbing but, contrary to the title of the chapter, they report mostly on non-breeding birds. Chapter 4 addresses dispersal, flocking habits, and home ranges in non-breeding birds. Described in these chapters are intriguing behavioural actions whose function remains unclear, such as "funerals" (the mobbing of a dead magpie), "ceremonial gatherings" (apparently a form of territorial probing, not observed in North American magpies), and communal roosting.

Following Chapter 5 on feeding and food hoarding (in which we learn that, contrary to folklore wisdom, magpies do not steal and hide shiny objects), and Chapter 6 on magpie populations, the reader comes to three chapters on the breeding cycle: nests, eggs, and incubation (Chapter 7), chicks and their care (Chapter 8), and breeding success (Chapter 9). Chapter 10 examines the factors affecting breeding success, most notably bird and territory quality. Food resources emerge as the main determinant of breeding success, with predation and the quality of parental care acting as secondary factors.

Chapter 11 is entitled "Magpies and man". In it, Birkhead explores the love-hate (mostly hate) relationships magpies have had with farmers, gamekeepers, and townspeople. In a particularly interesting study, Stephen Gooch, Stephen Baillie, and Birkhead used hard data to explode the myth that magpie predation affects songbird density. Songbird success and density did not decrease (actually, it sometimes increased) with increasing magpie density, at least in rural areas. When it comes to songbird mortality, Birkhead blames instead a predator that few people hate: the domestic cat.

Throughout the book, comparisons are made between the two species of magpies, and between the North American and European races of *Pica pica*. Chapter 12 reviews these comparisons and makes the case for the Black-billed Magpie as a suitable subject for comparative and evolutionary studies.

Each chapter opens with a quotation, often from older works, and ends with a summary. The text is clearly written and peppered with humoristic anecdotes and comments stemming from the author's own experience with magpies, and his conversations with magpie researchers. The book is also well-researched; the reference section comprises 272 entries, at least 157 of which relate directly to magpies. In addition, the author presents some of his own original data. Each chapter is graced by beautiful drawings from David Quinn, who also did very nice color illustrations for the dust jacket and the frontispiece.

This fine book will not be out of place in the library of any amateur or professional ornithologist who comes into regular contact with magpies (in Canada this means ornithologists west of Winnipeg). Hopefully it will bring to its readers renewed appreciation for a bird whose behaviour is both fascinating and easily observed.

STÉPHAN REEBS

Département de Biologie, Université de Moncton, Moncton, New Brunswick E1A 3E9

Advances in the Study of *Peromyscus* (Rodentia)

Edited by Gordon L. Kirkland, Jr., and James N. Layne. 1989. Texas Tech University Press, Lubbock, Texas. 367 pp., illus. Cloth U.S. $35; paper U.S. $22.

This is the second volume in just over twenty years that is devoted to reviewing the biology of *Peromyscus* and it seems reasonable to ask why. These small (12-140 g) mammals are seldom economic pests, have no role as disease vectors, and rarely attract the interest of wildlife managers. They are, however, a popular choice of graduate students and have been the subject of innumerable theses. The deer mouse (*P. maniculatus*), in particular, will be familiar to most naturalists; this single species

ranges from Mexico to the Yukon, their numbers are relatively constant from year to year (a key factor for any student contemplating a 2-3 year study), they are easy to capture and handle (wrestling with a semi-anaesthetized predator may be more glamorous but sample sizes usually suffer), and, finally, they are easy to breed and maintain in captivity.

The original review (*Biology of Peromyscus*) was edited by John King in 1968 and attempted to cover all aspects of this genus; the present editors have chosen to focus on five fields that have seen "significant advances". A sixth and summary chapter by W. Montgomery covers important new ground and compares the North American *Peromyscus* genus with *Apodemus*, its ecological equivalent in Eurasia. In the past European mammalogists have complained, with justification, that their research was ignored in North America. Montgomery helps correct this imbalance by integrating the work that has been done on these rodents on both continents.

A chapter on adaptive physiology by R. MacMillen and T. Garland concludes that *Peromyscus* is a physiological generalist. The explanation of why they succeed in areas where conditions are occasionally severe (dry or cold regions) is attributed to the use of torpor. Interestingly the trend in body mass of *Peromyscus* goes against the prediction of Bergmann's rule; larger species of *Peromyscus* occur in the tropical south and smaller species prevail at high latitudes (this conclusion is tentative as there are few data from southern species). The systematics of *Peromyscus* are summarized in exhaustive detail by M. Carleton. This chapter claims one third of the book and its appeal, I suspect, may be limited to specialists.

One might expect life history strategies to vary among a genus with such a wide geographical distribution and J. Millar presents a thorough account of how *Peromyscus* reproduction and development rates vary. The final two chapters in this volume consider population biology (D. Kaufman and G. Kaufman), and social biology (J. Wolff). Surely one of the significant aspects of *Peromyscus* population dynamics is their relative constancy in numbers from year to year (cf. *Microtus*), yet the authors overlook this. Both of these chapters conclude by outlining the needs of future research: longer term studies with better replication, more interdisciplinary approaches, and adoption of standardized methods to allow broader comparisons between studies.

The interdisciplinary approach may be some time in coming to judge by the current volume. The book presents a reductionist view of *Peromyscus* — a series of topic specific chapters and the reader gets only a few glimpses of a whole animal adapted to its environment. Can we hope a third volume on *Peromyscus* will give us a more holistic view?

This is a solid contribution to the field of small mammal ecology and workers in this area (or biogeography) will find it interesting. It is unlikely that this book will appeal to readers with other backgrounds; obviously it should be required reading for any student embarking on their apprenticeship in *Peromyscus* biology.

B. SCOTT GILBERT

Arts and Science, Yukon College, Box 2799, Whitehorse, Yukon Y1A 5K4

Birds of the Lower Colorado

By K. V. Rosenberg, R. D. Ohmart, W. C. Hunter, and B. W. Anderson. 1991. University of Arizona Press, Tucson, Arizona. 464 pp., illus. U.S. $40.

Birds of the Lower Colorado is a report on several years of scientific research undertaken to investigate the ecological relationships among desert riparian wildlife. The output from this work is blended with historical data to produce a comprehensive picture of avian life from the Colorado state border at Page to the U.S.-Mexican border at Yuma.

In the early chapters the authors explain how the original state of the river has been changed by humans and how this in turn has affected the vegetation. Like most places on earth the original vegetation growing along the Colorado River had learned to adapt to the local conditions. These included both floods and droughts. Today the river is dammed and channelled for irrigation and to provide water to U.S. cities. The result is not only a drastic change in flow patterns and rates but increased salinity, increased number of large water bodies, and an increase in humans and their associated activities. All this has led to profound changes in the wildlife.

The authors describe their work to define the ecology of the original plants and thereby the needs of those species. Areas where such plants still remain were evaluated as bird habitat. The needs of residents and transients for breeding and feeding were carefully investigated. Not surprisingly an introduced plant, saltcedar, had managed to take advantage of the human disturbance and spread over large areas of land. This new habitat did not appear as productive as the original cottonwood and mesquite groves. The authors cleared a large tract of saltcedar and replanted it with native trees and shrubs, and studied the change in bird populations. The results

showed that their predictions of what the change might be proved correct, and that habitat improvement could yield significant benefits. (But why did they plant the trees in straight lines?)

The book is dominated by the species accounts, which are much more detailed than normally found in bird guides. For example, for the commoner species they include such things as status, habitat, breeding, and food habits. I found some of the data given under the latter surprising. In this region, Blue Grosbeaks and Song Sparrows are predominantly insectivorous, while Gambel's Quail eat a significant amount of rodent faeces in summer! The rarer species sections are restricted in the level of detail to status or status and habitat. At the end of the species accounts is a table of some data from the CBC's at three locations. I found this table was insufficiently detailed to be of value. A subsequent bar graph of seasonal status is far more comprehensive and useful. There is also an interesting series of seasonal histograms for 24 of the common migrants.

The authors' analysis of migration and vagrancy patterns will be welcomed by visitors, especially the tick hunters. All bird watchers eventually get to this area of the U.S., usually clutching their indispensable copies of "Lane" [*A Birders Guide to Colorado, A Birders Guide to Southern California* and *A Birders Guide to Southeastern Arizona*, by James Lane and others, L & P Press, Denver, Colorado]. There is much more to the birds of the south west than knowing where they live. This book provides a better understanding of not only what and where, but why the birds are there and what their fate might be. But buy your copy well ahead of time, for although it is well written, there is a lot to absorb. It will take time to read the different components but the payback will be a more successful trip.

The book has other uses beyond the area of the study. The work on conservation, breeding and feeding habits, we can hope, will help promote wise management of habitat, not only in this region but elsewhere. It is a fine example of a well run scientific program that has been put into a readable text for the non-scientist. It shows that biological research needs years of political and financial support to make solid progress, and how the information generated can be used in wise resource management.

I was a little surprised the authors did not discuss some of the other major issues on the Colorado. Acid rain is certainly a threat. Mining and ski resorts although generally located in the headwaters, must surely have a downstream impact. They missed an opportunity, at little extra cost, to have collected and interpreted data on Colorado's water quality and its influence on the region's ecology. The weather data they give is very spartan. In an area where weather is so important, this too is a little surprising.

Overall I found this a well written and very informative book. I will re-read it before my next trip to the South-west and I am certain it will add to my understanding and enjoyment of the region. Also I suspect I will be consulting it for other reasons, such as conservation issues, as well.

ROY JOHN

544 Ketch Harbour Road, Box 13, Site 2, RR#5, Armdale, Nova Scotia B3L 4J5

Crane Music

By Paul A. Johnsgard. 1991. Smithsonian Institution Press, Washington. 136 pp., illus. U.S. $19.95.

A recent annual statistical report on migratory birds within a northern U.S. state arrived in the mail. I was shocked to see that Sandhill Cranes are included among the "harvested" birds, and doubly shocked at the figure of 17 000 taken. Saskatchewan and Manitoba contribute an additional 6946 to the harvest. It is, to me, incomprehensible that this is sport. In his book, Johnsgard mentions hunting of Sandhill Cranes but (rightly) is more concerned about loss of habitat. The Sandhill Crane is holding its own at the moment, but their major staging area, the Platte River in Nebraska, is an endangered river. Up to 500 000 cranes gather there each spring before flying to the Arctic to nest. The flow of the Platte has already been reduced by half, and the river is threatened by more dams and factories. In spite of full protection in the rest of the world, crane populations are declining. The figures are not encouraging, as illustrated in a table giving world populations and the status of all species, but perhaps the International Crane Foundation will improve the outlook as it grows in influence.

This slim volume is a précis of the seven previous books Johnsgard has written about cranes and is a primer for a general reader. The majority of the book is about Greater and Lesser Sandhill Cranes — their breeding, feeding and migration patterns. A short chapter describes Whooping Cranes ("the conservation symbol of America") and the remaining 13 species of cranes in the world are briefly discussed.

There is some interesting discussion, with good illustrations, of crane dancing, an activity which is not specifically confined to territoriality and dominance. Sometimes it appears to be exuberant high spirits — what a happy thought.

Crane Music would make a useful addition to a birdwatcher's library.

JANE E. ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T6

Ravens in Winter

By Bernd Heinrich. 1989. Simon and Schuster, New York. 379 pp., illus. U.S. $19.95.

Why does one food source attract 50 or more ravens and another source nearby only two ravens, or none? *Ravens in Winter* provides some answers – and raises more questions.

Almost alone among northern birds, ravens appear to 'recruit' others to share food sources. It took Heinrich eight winters to prove how they do it, to his satisfaction. He hauled carcasses of road kills and dead farm animals (including sheep, calves, and, once, a whole cow) into the Maine woods to study feeding behaviour. They must have large appetites: the local ravens ate 8 tons of food over four winters.

He found that when a juvenile raven (pink mouth) or an unpaired adult (black mouth) discovers carrion in the territory of a resident pair it will feed on it only when it can return with other ravens, usually the next day. This is probably for "safety in numbers" against attack either by a resident pair of ravens or by predators. Using a unique call, recruitment can bring in birds from as far away as 60 miles from the site. In contrast, when a resident pair discover food on their territory they feed without "advertising" its presence, though if a number of other ravens do join them, there is little aggression towards the newcomers. This account of his hours of watching baits (initially in an unheated summer cabin for 4 or 5 days at a time), his frustration when there appeared to be no consistent pattern of behaviour, his relish in surviving the cold and the blizzards, and in finally achieving firm results, makes good reading not least because of his enthusiasm for the research. The illustrations, which are small drawings of various plumage displays, are undistinguished except for that of the dominance 'ear display' – similar to the 'ear' tufts of a screech owl.

The final summary chapter puts all the field observations into focus and makes some hypotheses for future research. Although this is a scientific book, readers are spared footnotes and numbered references in the text and they are grouped at the end with 21 graphs. This is an excellent book for ethology students interested in a detailed analysis of one aspect of a well known species.

JANE E. ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T6

Bird Trapping and Bird Banding: A Handbook for Trapping Methods All Over the World

By Hans Bub. 1978. (Translated from German by Frances Hamerstrom and Karin Wuertz-Schaefer. 1991). Cornell University Press, Ithaca. 330 pp., illus., U.S. $69.50.

This book is a comprehensive survey of methods for capturing live birds. It is written by an experienced bird-bander who drew from his own knowledge as well as that of numerous colleagues. The breadth of coverage is impressive (indeed, a tribute to people's ingenuity when it comes to catching live birds): fall traps, funnel traps, cage traps, pit traps, mist nets, trammel nets, drop nets, bow nets, clap nets, pull nets, cannon nets, nooses, catching at night, special devices for ducks, raptors, shorebirds, etc. There is even an entertaining description of how one Danish bander catches gulls by hand after burying himself in refuse at a garbage dump!

Excellent details are given on how to build the catching devices, and also on where, when, and how to set them. Such details are the main forte of the book. There is also a short chapter on the holding and handling of birds before, during, and after the banding operations, but the emphasis is on trapping and not on banding per se. Nevertheless, banders will appreciate the list of manuals and periodicals on bird banding at the end of the book, as well as the extensive bibliography (beware, however, that most of it is in German). There is a very useful species index but no subject index (although the table of contents is so detailed that it can be construed as one).

The book has two limitations. First, although techniques from all over the world are described, there is an understandable bias in favour of European examples. North American readers should not be bothered by this, however, as most of the techniques can be adapted to North American species. Second, this being the translation of a book published in 1978, none of the techniques developed in the last decade and a half are included. However, it is fair to say that new techniques are usually modifications of a basic design, and basic designs are very well covered in this book.

The quality of presentation is high. There are a few typos but this is not unusual in a work of some 370 000 words. No less than 456 figures and photographs accompany the text. Overall this is a fine book that should provide great information, if not inspiration, to ornithologists who wonder how to best capture their favorite species, and to those who seek knowledge on the diversity of bird-catching methods.

STÉPHAN REEBS

Département de Biologie, Université de Moncton, Moncton, New Brunswick E1A 3E9

The Secret World of Animals: Under the Water

By Kevin Chu, Chris Clark, Peter Tyack, Alan R. Emery, and Carl Hopkins. 1991. Canadian Museum of Nature, Ottawa. Audio tape. 1 hr. $10.95.

Under the Water is one in the series of audio tapes entitled *The Secret World of Animals*. This tape includes interviews with five researchers, currently working on the sensory systems (both sound and electrical) of marine and freshwater organisms, and is accompanied by recordings of a variety of marine and freshwater animals. The various "authors" discuss aspects of their research and present information on sound production and the functions of sounds in a wide range of organisms, from whales and dolphins to fish and insects. Although based both on the scientific findings of the "authors" and on findings of other researchers, the tape content is aimed at a general audience, and is probably suitable listening for a wide range of ages.

The aquatic world poses many problems to animals in terms of how they sense their environment. As visibility is limited, sound appears to play a greater role in communication than is found in terrestrial systems. For humpback whale songs, Kevin Chu discusses how the sounds might be produced, the structure of the songs, and some of their potential functions. The speakers review a broad range of methods of studying the functions of underwater sounds, which provides the listener with as much information about the processes of the scientific method as it does about the details of what is known about the sounds of these animals. Chris Clark first reviews the social calls of right whales, and then discusses and presents a recording of bearded seals and bowhead whales. Peter Tyack discusses the sounds produced by bottlenose dolphins in captivity, and how the study of sounds from captive animals may be applied to understanding the function of these sounds in the wild. Alan Emery examines the sounds of a variety of species of fish, shrimp, and insects, and discusses how slowing down the sounds during playback can help in understanding and elucidating their function. Carl Hopkins concludes with a discussion of electrical discharges from certain species of fish, and how such electrical pulses may be used in communication. He has translated the electrical pulses into sound, to aid in the interpretation and understanding of this sensory modality.

Clearly our perception and comprehension of the complexities of sounds produced by other animals is aided by being able to hear them, rather than just to read about them, and this "talking" book does a wonderful job at making such information available and easy to understand. As well, it goes beyond the sounds themselves and emphasizes both the behaviour of the organisms, and the large diversity in the methods of study of the functions of animal sounds.

ROBIN W. BAIRD

Marine Mammal Research Group, Box 6244, Victoria, British Columbia V8P 5L5

Birds and Islands: Travels in Wild Places

By Ronald Lockley. 1991. McClelland and Stewart, Toronto. 237 pp., illus. $39.95.

Anyone with an interest in natural history and a love of islands will be delighted with this book by veteran natural history writer, Ronald Lockley. Lockley, who over the years has travelled extensively around the world, has chosen to highlight eighteen of the islands he has visited. From the far northern islands off the coast of Alaska and Norway to the islands of the southern Pacific and Antarctic area, this book is sure to entertain armchair travellers and naturalists everywhere.

The author's lively writing style and diary entries result in some fascinating reading. One cannot help become absorbed in the text as the author recounts the occasion when he was precariously lowered off a cliff by rope, 250 metres above the roaring Atlantic to search for the Fork-tailed Petrel. He did not find the petrel but enjoyed observing the Faroe Shearwater and the abundance of puffins that nest in the burrows on the cliff face. The author stimulates the imagination of the reader when he shares his experiences while exploring a remote northern beach and whilst going over a small crest suddenly encountered a polar bear ambling towards him.

Though much emphasis is placed on birding as the title indicates, it is by no means restricted to this subject matter. While a great deal of emphasis is placed on bird identification, nesting habits, migration and behaviour, the author generously covers many other topics as well. The author recounts his observations of the culling operations of fur seals, comments on the breeding and raising of king penguins, as well as the social behaviour of the walrus. He readily identifies much of the plant life and remarks on differ-

ences in climate, terrain, and marine life on each island. On most occasions the author stayed in the homes of friends or islanders and is therefore able to give insight into different cultures, the mixed benefits of island life, self-sufficient lifestyles, and the unique characteristics of each particular island. As the author has visited many of the islands in earlier years, one can also benefit from his comments regarding changes or stable continuity of island life over the years.

The text is accompanied with detailed ink drawings by Noel W. Cusa and hand-drawn maps. Throughout the text the author often refers to or quotes from literary works relating to the subject matter, touches on the history of the islands and voyages of early explorers such as Captain James Cook.

Easter Island, the Falklands, Tahiti, or islands of the Canadian Arctic, whatever one's taste, *Birds and Islands* is a delightful armchair adventure from a naturalist's perspective to many of the remote islands of the world, each briefly but beautifully portrayed.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario K0A 2W0

Migrations: Travels of a Naturalist

By Bobby Tulloch. 1991. McClelland and Stewart, Toronto. 151 pp., illus. $44.95.

In this book, the reader follows the travels of the naturalist Bobby Tulloch as he explores his home turf of the Shetlands as well as some interesting habitats abroad.

His objective is to introduce the reader to a variety of species of birds as well as shed light on their behaviour and migratory patterns. He accomplishes this by adeptly conveying to the readers his extensive observations from recent and past excursions. Whether he is conducting land or sea tours, or frequenting local birding hot-spots, one cannot help but enjoy his interesting narratives.

A good portion of the text covers the composition of bird populations in the Shetlands throughout the various seasons. Tulloch highlights the differences between resident and transitory species as well as the various factors that can affect their migration.

Travelling further afield, Tulloch recounts his travels to the Falklands, the Arctic, the Seychelles, Lappland, and several islands of the North Atlantic. When describing birds of these areas, he often aids the reader by referencing a similar species which one can more readily identify. One will be absorbed in the text as the author describes visits to King Penguin colonies and sightings of the rare Dolphin Gull in the Falklands, and his observations at the waterfowl breeding grounds at Iceland's Lake Myvatn area.

There are other features that bear noting in this book. An abundance of colour photographs accompany the text and are of excellent quality. The photo-descriptions are lengthy and can be enjoyed while reading the whole book, or read independently. Though the illustrations may have artistic merit they have little value in aiding the reader in identification of species as they have a wash effect and lack crisp delineation. It should also be noted that the book unfortunately does not include any maps. It is highly recommended that one have an atlas close by to reference the islands and their specific areas that are discussed.

Tulloch succeeds in broadening the readers' knowledge of different island environments, migration patterns, and identification of numerous species of birds. His material is well presented, his coverage thorough, and one cannot help but vicariously enjoy his travels.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario K0A 2W0

BOTANY

Mushrooms of North America

By Roger Phillips. 1991. Little, Brown, Boston, Toronto. 319 pp., illus. Cloth U.S. $39.95; paper U.S. $24.95; $29.95 in Canada.

Interest in fungi has mushroomed during the past two decades. The increased awareness of the environment, ecology, natural history, and related areas has directed attention to the role of mushrooms and other fungi. Also, mushrooms have become a popular motif with artists and craftsmen.

Roger Phillips' book is the pleasing result of the art of a professional photographer melded with the interest of an avid mushroom enthusiast in the technical distinctions between species. Both the composition and reproduction, especially the critical colors, of the photographs is excellent. With over 1000 species illustrated in color photographs, it contains the most varied selection of North American mushrooms yet published. For example, forty species and

varieties of the genus *Amanita* are pictured. All the common, the popular edible and the poisonous species are included, as are a variety of rare or unusual mushrooms.

This is a book of pictures; about 65 per cent of the 319 pages is devoted to photographs. The descriptions and notes on habitats and edibility occupy a distinctly subordinate role. The short introduction discusses such topics as "What is a mushroom?", collecting hints, poisoning symptoms, popular edible species, how to go about identifying wild mushrooms, and an explanation of the technical terms it was necessary to use in the book.

Unfortunately the illustrations of *Oxyporus populinus, Poronidulus conchifer, Hydnochaete olivacea,* and *Auricularia auricula* have been inverted, but they are the type of fungi where it doesn't have a disastrous effect. The photograph labelled *Trametes pubescens* shows a variety of *T. versicolor* and not *T. pubescens.* In a few photographs the mushroom is so small that the technical details, needed to accurately identify it, are obscure; e.g., *Panellus stipicus.* But these are minor inconveniences.

This is a highly recommended, modestly-priced volume for anyone interested in mushrooms, and for naturalists who should be aware of the variety to be found and their important role in the environment.

J. GINNS

Centre for Land and Biological Resources Research, Agriculture Canada, Wm. Saunders Building, Ottawa, Ontario K1A 0C6

Fungi Without Gills (Hymenomycetes and Gasteromycetes): An Identification Handbook

By Martin B. and J. Pamela Ellis. 1990. Chapman and Hall, New York. x + 329 pp., illus. U.S. $79; $99 in Canada.

The first volume in this series of identification handbooks, titled *Microfungi on Land Plants,* was reviewed in *The Canadian Field-Naturalist* 100: 448–449 (1986). The kingdom of the Fungi is composed of two major classes, the Ascomycetes and the Basidiomycetes. Fungi with gills are mushrooms and they are Basidiomycetes. Fungi without gills are the large Basidiomycetes other than mushrooms, such as boletes, polypores, puffballs, toothed fungi, stinkhorns, jelly fungi, and coral fungi.

The series is designed to encourage interest in the fungi and especially in those groups of fungi which require the use of a microscope to accurately identify collections. Although based upon the fungi in Great Britain, most of the species also occur in North America. However, the book is not comprehensive and our mycoflora is more extensive than that of Great Britain.

Most of the book is a series of keys (statements of contrasting characters) and brief descriptions of the pertinent distinguishing features of the genera and species. There are 974 species treated and 543 are illustrated. A host index, glossary and the ink drawings of fruiting bodies and microscopic features, such as spores and cystidia, conclude the volume.

This is an excellent series and no comparable work exists for Canada or the United States. The book presents information on taxonomically and ecologically diverse groups of fungi, which previously was widely scattered in the literature. It will be a big help to mycologists, plant pathologists, ecologists, and others who have to identify these fungi in their work. Hopefully it will stimulate interest in students, amateurs and professionals to the point that a similar book will be prepared exclusively for the North American mycoflora.

J. GINNS

Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario K1A 0C6

A Natural History of Trees of Eastern and Central North America

By Donald Culross Peattie with an Introduction by Robert Finch. 1991. Reissue of 1948 edition. Houghton Mifflin Company, Boston, xvii + 606 pp., illus. Paper U.S. $16.95.

A Natural History of Western Trees

By Donald Culross Peattie with an Introduction by Robert Finch. 1991. Reissue of 1950 edition. Houghton Mifflin Company, Boston, xvii + 751 pp. Illus. Paper U.S. $18.95.

These two treasures, first published in 1948 and 1950 respectively, and reprinted several times, contain a wealth of interestingly written information about the various trees which are native to the eastern and western parts of North America.

In each of these volumes, one to several pages are devoted to each species. At the end there is a simple key to the species, a glossary, and indexes to scientific and common names. For the individual species, common names (accepted and alternate), scientific

names (a few of which are now out-of-date), range, and an easily read description are presented. The important part, however, is found in the following paragraphs which include such things as childhood reminiscences, interesting uses, relationships with other species, comments about individuals associated with them, the history of diseases such as the Dutch Elm disease and its spread, use in building and the advance of lumbering, and many other observations, all presented in a delightful and easy-to-read manner. Unfortunately the additional volumes on "southern" and "cultivated trees of exotic origins" which were planned by the author never reached the publishing stage.

WILLIAM J. CODY

Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario K1A 0C6

Vascular Flora of the Southeastern United States: Volume 3, Part 2, Leguminose (Fabaceae)

By Duane Isely. 1990. University of North Carolina Press, Chapel Hill, xvii + 258 pp. U.S. $35.

As explained in the preface of the first volume (1980) of the planned five volume *Vascular Flora of the Southeastern United States,* the general objectives are as follows:

"1. To survey floristically the forested region of the southeastern United States west to the prairie and north to the southermost terminal moraines. This region includes Delaware, Maryland, Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Tennessee, Kentucky and West Virginia. Notation of presence in the adjacent states of Texas, Oklahoma, Missouri, Illinois, Indiana, Ohio, Pennsylvania and New Jersey will be made. (No effort has been made to include total distribution beyond the adjacent states.)

2. To produce a Manual that will include keys, descriptions, habitats, distributional data, and pertinent synonymy to every vascular species growing without cultivation in the southeastern United States."

The Editorial Committee for the Flora has decided that "Because of the importance and size of this family [Leguminosae], we have elected to treat these plants in a separate volume. To place this in taxonomic sequence, it is assigned as Volume 3, Part 2. Volume 3, Part 1, will include other members of the Rosidae, and Volume 2 will include the ferns, gymnosperms, Magnoliidae, Hamamelidae, and Caryophyllidae." No mention is made however as to projected publication dates for Volume 2, Volume 3, Part 1 or Volumes 4 and 5. Hopefully we will not have to wait another 10 years for the next one.

The format is outlined in the introduction and is considerably more detailed than in most other floras. Particularly useful are the two maps which depict the Physiographic Provinces of the Southeastern United States and the Floristic Provinces of the Eastern United States. The abbreviations which appear on them are used throughout the text. It would however have been helpful to those who are not completely familiar with United States geography, to have included the names of the states, even if in small print, on the larger of the two maps.

The area covered by this flora is approximately one fifth of continental United States, excluding Alaska. Here there are some 393 species of Leguminosae, mainly in the subfamily Papilionideae, but the subfamilies Mimosoideae and Caesalpiniodeae are also represented. Good illustrations that depict characters that differentiate these three subfamilies are to be found with the descriptions of the subfamilies but the individual species are not illustrated. Genera and species are described carefully and concisely, together with the additional information as outlined in the objectives. Useful and interesting information is also often provided. In addition, numerous subspecies, varieties and hybrids are also described and discussed in some detail. Species that have been rejected are listed at the end of the genus, usually with a very short description, together with references of previous reports and the reasons for rejection; some are to be found in the keys.

Appendix 1 comprises selected bibliographies: General references to Leguminosae, Floristic treatments of Leguminosae of the United States, References to cultivated species, and Horticultural tree and shrub references. Appendix 2, entitled Systematics of the Leguminosae presents a brief "Historical Accounting of Legume Classification" and "Classification of Legumes in the Southeastern United States". A Glossary, Literature Cited, and Index are also provided.

Dr. Isely, who has written extensively on the Leguminosae of the United States since 1948, is to be complimented on this excellent and most useful treatment of the legumes of the Southeastern United States.

WILLIAM J. CODY

Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario K1A 0C6

Vascular Plants of Minnesota, A Checklist and Atlas

By Gerald B. Ownbey and Thomas Morley. 1991. University of Minnesota Press, Minneapolis, xi + 308 pp. U.S. $39.95.

This most useful publication represents the culmination of many years of study of the vascular plants of Minnesota — indeed the second author began the mapping project in 1962. The text following the introduction, which provides a most useful background, is divided into two parts: Checklist and Atlas.

But the checklist is not just a plain list. it contains a wealth of pertinent references that will be invaluable, not only to those working on the flora of Minnesota, but also the surrounding regions. Also included here are common names, pertinent synonymy, for non-native species "Naturalized" or "Introduced", and even such comments as "The proposed varieties are not distinguishable". An Appendix to the Checklist comprises a list of excluded species, and a second Appendix presents tables showing the breakdowns for the 2010 taxa listed.

Part 2 consists of 1881 distribution maps which show the positions of the 87 counties and depict the exact locations of the various collections – not just a single dot in the middle of a county. These are preceeded by a larger map showing the names of the counties, plus an alphabetical list of county names with a key to their locations. There are maps for all the native or presumed to be native species, even if some are known only from a single locality, plus introduced species that have become naturalized. Excluded are other introduced species that may occur from only time to time, but are not persistent. A comparison of these maps, as pointed out in the introduction, will demonstrate the dividing lines between the western limits of the eastern forest flora and the northern and eastern limits of the flora of the prairies and plains. Rare species can also readily be detected.

Knowledge of the flora of Minnesota has gradually increased through various publications starting in 1822, with the first comprehensive list in 1875 and the last in 1946. In addition, Olga Lakela published *A flora of northern Minnesota* in 1965 and Thomas Morley published *Spring flora of Minnesota* in 1974. As yet however no comprehensive flora of Minnesota exists. With the present checklist in hand, the writing of such flora should be a much easier task.

WILLIAM J. CODY

Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario K1A 0C6

The Illustrated Field Guide to Ferns and Allied Plants of the British Isles

By Clive Jermy and Josephine Camus. 1991. Natural History Museum Publications, London, England. X + 194 pp., illus. Paper £7.95.

Naturalists planning to visit the countryside of the British Isles will find this publication on the ferns and fern allies a welcome companion. The black silhouettes which are accompanied by fine line drawings of diagnostic parts where needed, are particularly useful. With these, the descriptions are not lengthy, but the important items are emphasized by the use of bold face. The notes on habitat and distribution are most helpful, as are the many other pertinent comments found throughout. There are 72 species known in the area — the challenge now is to go out and find them.

WILLIAM J. CODY

Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario K1A 0C6

Manual of Vascular Plants of Northeastern United States and Adjacent Canada

By Henry A. Gleason and Arthur Cronquist. 1991. Second Edition. New York Botanical Garden, Bronx, New York. LXXV + 910 pp. U.S. $74.60 in U.S.A.; U.S. $76.90 elsewhere.

This second edition is based on the first edition published in 1963, which in turn was based on the *New Britton and Brown Illustrated Flora,* published in 1952. As pointed out by Dr. Cronquist in the preface to the first edition, where the manual resembles the first printing of the *Illustrated Flora,* it is the work of Gleason, and insofar as it differs, it is the work of Cronquist. Now in the second edition Cronquist takes full responsibility for the entire contents.

Perhaps the most obvious of changes is that the families of angiosperms follow the more modern arrangement proposed by Cronquist (1988) in his *Evolution and Classification of Flowering Plants,* rather than the Englerian arrangement followed in the first edition and many other floras. This may

pose some problems for those using the book for the first time when they are familiar with the old order, but with use this should readily be overcome. Throughout the text the user will find that some additional species are included, the occasional genus has been split, and that in many of the species descriptions additional information has been provided along with a general polishing of the text. In part for this, Dr. Cronquist acknowledges the help of a large number of individuals in the Preface, but the production of such a volume as this is a monumental task, and Dr. Cronquist is to be congratulated for having brought this most useful work to completion.

WILLIAM J. CODY

Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario K1A 0C6

Common Poisonous Plants and Mushrooms of North America

By N. J. Turner and A. F. Szczawinski. 1991. Timber Press, Portland, Oregon. xv + 311 pp., illus. U.S. $55.

A thoughtfully prepared, nicely presented book on a topic which has been quite prominent in recent years. The information on various types of poisoning, various types of plants and mushrooms that cause poisoning, various types of treatments for poisoning, and various related topics is well organized. From the book's beginning with "What to do in case of poisoning" and "How to prevent poisoning", both sections of a couple of pages, to the final sections on "Honey poisonings" and "Some medicinal herbs of questionable safety" there is a wealth of pertinent and fascinating information.

The main chapters are (a) the introduction to poisonous plants, (b) poisonous mushrooms, (c) poisonous plants of wild areas, (d) poisonous garden and crop plants, and (e) poisonous house plants and plant products. Most of the plants and mushrooms discussed are illustrated in colour. The 215 colour pictures are good but some of the mushroom photographs are tinted an atypical pink. The format for each plant or mushroom is consistent and composed of the following: common name and family, scientific name and family, quick check, description, occurrence, toxicity, treatment, and notes.

The authors designed a book "intended for parents, hikers, wild food enthusiasts, and health care workers in poison control centres" and I believe they have succeeded most admirably. It is a good book to browse through and to gain a better understanding of that plant that lurks next to the piano.

J. GINNS

Centre for Land and Biological Resources Research, Agriculture Canada, Ottawa, Ontario K1A 0C6

ENVIRONMENT

Extinction, Bad Genes or Bad Luck?

By David M. Raup. 1991. W. W. Norton, New York. 210 pp., illus.

The ball began to role in earnest in 1980 when physical evidence pointed the finger at an extraterrestrial object as the cause of the extinction event 65 million years ago which included our favourite fossil forms, the dinosaurs among others. David Raup, a statistical paleontologist with the University of Chicago has produced the latest volume in the field and, unlike his earlier book, *The Nemesis Affair* which was more of a personal journal of his involvement of the developing scenarios of extraterrestrial causes of extinction and the "ways of science", Raup's latest book involves the understanding of biostatistics.

By using biostatistics (as frightening as this word may sound to the general reader, Raup is very careful not to lose the reader in numbers), Raup is able to show that the other side of evolution, extinction, is not a signal of failure but merely a component that "adds another element to the evolutionary process." As well, the early record of life shows that species start out in small numbers and, because of this small population, are easy to wipe out by natural causes. Species that are widely distributed have more strength against extinction because natural causes are often not global. However, as seen in the geological past, global events have indeed happened and a catastrophic event previously not experienced by the species could cause such an extinction. This is the "bad luck." Massive extinctions in the past showed no preference to their victims: they transcend all ecological boundaries.

The modern analogy of the heath hen is an important symbol in two respects: the impact our species has on the biosphere and as a comparative tool. The geographic range of this bird was relatively large prior to human territorial expansion and hunting. These circumstances are what Raup calls the "first

strike" ("new and sudden stress" on a population). The second and final stage of the heath hen's demise was natural – fire, predation, and disease decimating the much reduced population.

From here we can draw our own conclusions. The widespread extinction of species today, primarily the result of habitat loss, is a "first strike". We are the catastrophic ingredient of today. Tomorrow, a fire, a storm, or whatever may kill the remaining population of some seemingly far off species.

Extinction offers not only imaginative examples of our past but persuades us (if we really need persuasion) that extinction is normal, but at times also devastating. His tool is the interpretation of numbers. This book is an important read for any one concerned about the earth's past and current ill health.

TIM T. TOKARYK

Saskatchewan Museum of Natural History, 2240 Albert Street, Regina, Saskatchewan S4P 3V7

Human Activity and the Environment 1991

By Statistics Canada. 1991. Canada Ministry of Science and Technology, Ottawa. 237 pp., illus. $35 in Canada, U.S. $42 in U.S.A., U.S. $49 elsewhere.

I have used the previous, 1986, version of this publication extensively, both as an indicator of the availability of more detailed statistics on the Canadian environment and as a general source of comparison with historical, local, or international environmental trends. The present, 1991, version should prove of similar value. The cost did seem high, to me, for a paperback edition, but hopefully it represents an attempt to reduce our tax contributions.

The statistical data summarized in this publication cover a broad range of topics. The information is fairly general, but provides a good indication of what is available within the Statistics Canada databases as well as the sources to obtain more detailed or localized data. Information on country-wide or historical trends is well covered. There is intriguing information on almost any area of the environment, as well as some data which are quite peripheral to the topic. Examples of the latter are the tables of gross domestic product by industry, merchandise imports and exports, and selected household expenditures for 1986.

Some examples of what I found to be very interesting statistics follow, to illustrate the range of topics covered. Federal Government expenditures on resource conservation have steadily declined from 1984 to 1990, while their costs for garbage and sewage disposal have steadily increased. Employment in Canada by industrial impact class has gone down over the past 16 years in resource intensive industries (from 32% to 14% of the country's total employment), while the energy intensive, contaminant intensive, and water intensive industries have all increased. Historical tables indicating substantial increases in birth rate, immigration rate, and life expectancy provide some of the reasons why. Documentation of our environmental legislation and its enforcement will be of interest to many and concern to many others.

Encouraging data on natural resources are also provided. Canada's whooping crane population has almost tripled from 1966 to 1990. Peregrine falcon numbers have increased 14 times since 1970. Breeding bird populations which are documented by ecoregion, also indicate many more increases than decreases over the 1966-1989 period.

Some of the mapping provided is a little small in scale to be used for accurate purposes. I was also a little at loss as to what the case history of the Jock River environmental assessment added to the value of the document. I found it confusing in the use of terms such as "environmental assessment" which appears to represent monitoring rather than predictive planning and management, "EIS" for environmental information system, etc. I felt there are much better examples if the purpose was to document the environmental assessment process in Canada. I was also concerned over the up-to-date nature of some of the statistics provided. We are told about on-line databases, sometimes updated weekly, computer data banks, and up-to-date geographic information systems (GIS). Many data are produced up to 1990 with future projections. However, in the critical areas of wetlands, forest cover, and agricultural lands, the best known data only seem to be up to 1986. Surely our satellite technology and GIS computer data management can do better than this?

All in all, I recommend the book as an indication of general environmental trends as well as the availability of more specific data. Because of the cost and the need to follow up with more issue or site-specific data sources, it is probably more of a library reference than a personal purchase document for most people.

WILSON EEDY

Beak Consultants Limited, 14 Abacus Road, Brampton, Ontario L6T 5B7

Causes of Evolution: A Paleontological Perspective

Edited by Robert M. Ross and Warren D. Allmon. 1991. University of Chicago Press, Chicago. xiii + 479 pp., illus. Cloth U.S. $65; paper U.S. $24.95.

In order to shed new light on some old problems in evolutionary thought, the editors of this volume decided to perform an experiment. Following a highly successful seminar series in paleontology at Harvard University in 1987, they solicited papers from the participants, asking them to address the question of cause in evolution. Using data from their individual research efforts, the authors were instructed to identify the principal causal factors controlling evolution in the organisms they were studying. More specifically, they were asked to explore the relative roles of biotic and abiotic, extrinsic and intrinsic factors in directing these changes.

The editors wished to test the idea that by explicitly defining the categories in which causal factors belonged these factors would then be subject to much more critical evaluation and possibly lead to additional hypotheses of cause. Secondly, they hoped to show how various disciplines, specifically paleontology, contribute to the process of classifying these causes.

In his foreword to *Causes of Evolution,* the noted systematist and author, Stephen Jay Gould, expresses wonder at how completely the essayists stick to the topic at hand. The care that they take to address the causal dichotomies selected by the editors and the precision with which they delimit them makes the experiment succeed beautifully. In addition, the papers do much in the way of heightening the reader's perception of the contributions of paleontology to evolutionary research in general.

The contributors to this volume present us with a wide array of subjects, from snails to hummingbirds to giant sloths. Despite this variety, each essay succeeds in the same way by giving the reader a different perspective for looking at problems in natural history. As such, this book is recommended to anyone who is interested in evolution and would appreciate a different way of thinking about it. For the person who is interested in evolutionary theory and feels that they have been neglecting the contributions of paleontology in their reading, *Causes of Evolution* is the perfect remedy.

LESLIE R. GOERTZEN

Department of Botany, University of British Columbia, Vancouver, British Columbia V6T 2B1

The Miner's Canary

By Niles Eldredge. 1991. Prentice Hall Press, Toronto. 246 pp., illus. $20.

An earlier book by Niles Eldredge, *Life Pulse,* was supplementary reading for my historical geology class. Concise and easy to read, it presented the major evolutionary events throughout the Phanerozoic Eon with less emphasis on extinction. His latest work, *The Miner's Canary* accentuates the role that extinction has played in the past and what is currently unfolding. It is a good companion to *Life Pulse.*

Niles Eldredge is co-founder, with Stephen Jay Gould, of the concept of evolution occurring rapidly at times with relative stasis between evolutionary bursts, i.e. punctuated equilibrium. In order for this concept to be valid, vast ecosystems (not just individual species) have to have become extinct in order for the rapid radiation of new forms. This can be seen in the past (the terminal Cretaceous event that claimed the king of fossildom, the dinosaurs and the rapid early Tertiary evolution of mammals, for example).

Eldredge points out in *The Miner's Canary* that individual species extinction has little affect on the ecosystem and in this respect is part of the natural evolutionary forces. Massive extinctions of both large and small organisms, relatively simultaneously, are quite different. Some type of indiscriminate force(s) affects all levels of the food chain. Current evidence points to temperature drops and changes in the sea level for many of the events in the past. An impacting extraterrestrial body also figures in on catastrophic extinctions.

Throughout the book the tropical island of Madagascar is cited as a modern analogy for past extinctions. Madagascar's isolation led to the evolution of a unique fauna and flora and the activities of our species, who arrived only 2000 years ago, have caused extinctions nearing the catastrophic level. From an estimated 11.2 million hectares of forest prior to human occupation to 3.8 million hectares in 1985, the deforestation has serious ramifications towards the survival of endemic species of lemurs, baobab trees, and birds (there are 150 endemic avian species in Madagascar) to name a few.

Noting that extinction is a common phenomenon which opens new space for evolution to operate, *The Minter's Canary* illustrates how lucky we really are to enjoy the earth's biological diversity. By preserving "component parts" of the global ecosystem rather than individual species our ecosystem may be here tomorrow for the next generation to cherish.

TIM T. TOKARYK

Saskatchewan Museum of Natural History, 2340 Albert Street, Regina, Saskatchewan S4P 3V7

Foundations of Ecology: Classic Papers with Commentaries

Edited by Leslie A. Real and James H. Brown. 1991. University of Chicago Press, Chicago. 1000 pp. Cloth U.S. $70; paper U.S. $27.50.

When this book crossed my desk I looked at the title and decided that it would be one which I could look at when time permitted, a lot of time. Soon after, I looked at it again and immediately spent time discovering its secrets, which were not really secrets at all since I had come across the material in science textbooks, lectures, and conversations with ecologists as long as I can remember. But here they were in front of me, in the original form from the original people who began the speculations about ecology and communities struggling for space, food, light, and all of the other things which determine how and where plants and animals live.

At first I tried to read every paper in order but soon found myself bogged down. So I read the commentaries which showed me the progression of thought in the various areas and the scientists who made the observations and from their recommendations, I moved to the papers in each section. Even reading just a few papers took me some time (my original fear was justified) but I eventually made it through most of the papers and I feel richer because of the experience.

The book begins with papers from the earliest days when ecology was just becoming recognized as a science, and follows with the theoretical advances of the science, mathematical formulae, and concepts of population and habitat pressures. The papers which caused debate in the scientific community are next, then on to the methodologies, case studies and experiments which have shaped the way ecologists study their science.

I was returned to history when I read *The Lake as a Microcosm* by Forbes, and to my earliest science texts with Cowles, *The Ecological Relations of the Vegetation on the Sand Dunes of Lake Michigan*. Hutchinson's familiar style again captivated my attention as I was reintroduced to the niche concept and species diversity. von Post's *Forest Tree Pollen in South Swedish Peat Bog Deposits* reminded me of the names associated with that familiar study, and so on through the rest. I am happy to pass this book on to other biology teachers and students and I am sure all who have the time will find something fascinating in the history.

I often became lost as I read and had to leaf back to the index to remind myself which paper I was looking at and when it had been written. The editors copied all of the papers right out of their original journals without changing to a standard format. The journals were not all easy to read and the print style was variable and sometimes difficult. I would have liked to have seen the papers rewritten into a standard format and references included at the top of each page. As I reviewed, I put the book down often and took it up again, so the papers did become confused in my mind. Notwithstanding the difficulty in reading, I think that the editors have done an excellent job gathering the materials and choosing the papers to be presented. I have my favourites and I would consider a couple of others to be essential. As the editors mentioned in the introduction, individual preferences are bound to occur and not all choices can be included in a single volume or a 40-paper selection list. I think their choices are well selected and the concept of such a volume appeals to me immensely.

JIM O'NEILL

Site 12, Box 21, SS 1, Sudbury, Ontario P3E 4S8

In a Patch of Fireweed

By Bernd Heinrich. 1991. Harvard University Press, Cambridge, Massachusetts. Reissue of 1984 edition. 194 pp., illus. U.S. $8.95.

Research scientists adhere to time-proven methods and procedures, adding pieces to the jigsaw puzzle of knowledge about our world. There are a few who are also inspired, and possess the rare ability to think laterally. Bernd Heinrich is among the latter, and this part-autobiography, part-study, provides some insight into his thought processes.

His early childhood was spent dodging the armies fighting in eastern Europe at the end of World War II, and he and his family spent the post-war years living in a forester's hut near Hamburg. They had no means of livelihood and ate mostly the wild flora and fauna of the forest. Heinrich had no toys or playmates, and had to help gather food. Crisply fried mice make a gourmet meal! As he gathered and hunted, he became fascinated by the ecosystem of the forest, and this experience laid the foundations of his later career in America.

He is a pioneer in the fields of biological energetics and the physiology of thermoregulation in animals. Case studies of his experiments in these fields comprise the major part of the book, and the descriptions of his efforts to take the body temperature of bees, hornets, and dung beetles in the field are very funny. The original devices he built to measure wingbeat

efficiency and heat production by insects are masterpieces of ingenuity. It is the thought processes behind the research which are the most interesting.

Since the first edition of this book appeared in 1984, Heinrich has published *One Man's Owl* and *Ravens in Winter*, which are equally well written. Judging by the exquisite drawings in all three books, he could also have been a successful artist.

This is an absorbing book which scientists will find as interesting as natural history buffs.

JANE E. ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T6

MISCELLANEOUS

Pioneer Ecologist: The Life and Work of Victor Ernest Shelford 1877–1968

By Robert A. Croker. 1991. Smithsonian Institution, Washington. xviii + 222 pp., illus. U.S. $27.50.

A name which still appears in considerations of community ecology and conservation, the long-lived Shelford receives a competent and sympathetic presentation and evaluation in this biography. After a boyhood in upstate New York, Shelford studied at West Virginia and Chicago with a thesis on variation on tiger beetles, and toured Europe. Showing how the distribution of species is an outcome of physiology and behaviour, his early experiments and field work on the fish and flora of Lake Michigan brought him colleagues and graduate students at Chicago. Made a Fellow of AAAS in 1913, he moved in the next year to the University of Illinois where his long and productive career included ecological research on insects, pollution, and marine systems. Extensive field trips, including to the Canadian tundra, were matched with the publication of major papers and texts, and participation in the Ecological Society of America of which he was founding president in 1916.

There was a long collaboration with Frederic Clements on the biome approach to communities, and ensuing controversy with Arthur Tansley. (Clement's term "biome" has spread to more general use, including the title of an educational publication of our Museum.) Deep concern for conservation, especially grasslands, led to involvement with federal committees and conservation politics in a fashion paralleling Aldo Leopold (whose biography by C. Meine is reviewed in *The Canadian Field-Naturalist* 103: 467–468). Shelford was a prime mover in the establishment of The Nature Conservancy which has grown to be a major force. The book contains a Foreward by François Vuilleumier and is well composed and illustrated with figures and plates. Appended material includes a chronology and impressive lists of supervised graduate students, with notable names such as Allee, Eddy, Kendeigh, and Powers.

This biography achieves a good balance of intellectual, personal, and family history. Shelford is not found wanting in any department. His studies are impressive for their considered depth and taxonomic breadth. Some of the topics, such as factors for predicting outbreaks of codling moths, have yet to be properly explored. Feminist historians of science should note that, as a dedicated instructor and supervisor of many students, he was egalitarian in his treatment of women. And there are attractive personal insights, as in his railing against "the preachers and those g.d. prohibitionists" and the devotion to grasslands (strange as this may seem to non-grasslanders) reflected in his insistence that the funds of the Grasslands Research Foundation be kept from hands east of the Mississippi River or west of the Rocky Mountains.

As with all good history, there are lessons for today: workers in whole-organism biology will smile to learn that in 1907 Shelford was advised to abandon ecology because reduction to physics and chemistry was at hand. *Plus ça change, plus c'est le même.*

PATRICK W. COLGAN

Canadian Museum of Nature, Ottawa, Ontario K1P 6P4

Fossils: The Key to the Past

By Richard Fortey. 1991. Harvard University Press, Cambridge, Massachusetts. 187 pp., illus. U.S. $29.95.

Popular books that introduce a subject are often written and illustrated in such a dry manner that the reader feels as if he were afflicted with narcolepsy. The authors of these coffee table books also often have a parochial knowledge of the subject matter. On the other side of the coin there are the textbooks written by professionals who try to cram in so much information that the quality of the writing is irrelevant or at most secondary. Avoiding both pitfalls and showing a lively literary style is Richard Fortey's *Fossils, the Key to the Past*. In this book fossils of all major groups are given life.

Fossils, the Key to the Past follows a typical for-

mat. A historical introduction is followed by an overview of the process of fossilization, sections on units of geological time (periods to zones), correlation and dating, and the physical forces that continue to shape the earth (tectonic forces, sea level, and climatical changes). In Chapter 4 (the longest of all the chapters) all the major groups are briefly described, including invertebrates (from protozoans to insects), vertebrates (jawless fishes to birds and mammals), and plants (from ferns to flowering plants).

Rather than just saying "here we are", fossils reveal more about themselves than one might expect (Chapter 5). For example, the sauropod dinosaurs were originally thought to be heavy footed thumpers that required swamp like environments to keep them going. More recent examination, however, reveals that they lived in terrestrial habitats, leading to the controversial topic of hot blooded versus cold blooded physiology (this still requires further investigation).

In light of current discussion of extinctions, we are now integrating the idea of the death of a species more closely with studies of its evolution (Chapter 6). By far the most extensive and popular look at extinction has concerned the Cretaceous-Tertiary event 65 million years ago which saw extinction of the dinosaurs as well as other organisms. Equally popular and extensively studied is the story of hominid evolution which can be traced with every other organism extinct and extant back to the origin of life itself (Chapter 7).

The closing chapters reveal how fossils can be used for our own materialistic purposes (mineral resources) and how current discoveries like the recently exhumed fish-eating dinosaur *Baryonyx* from Surrey, England, have changed and modified our views of the past. The final chapter tells how the layman can contribute to paleontological discovery by collecting fossils, recording the data, identifying, and storing a collection. However, little is said about the protection of fossils by various governments nor does Fortey emphasize the importance of amateur collectors notifying respective institutions of their finds. There is no sense in making a beautiful collection when it is kept in someone's basement and no useful information can be gained.

Leaving the best for last, I should note that throughout the book are hundreds of illustrations, photographs (predominantly black and white but some color) of some of the most exquisite representatives of preserved fossils (I presume the specimens are from the British Museum of Natural History). These, supplemented by a well researched though abbreviated text, make *Fossils, the Key to the Past* a worthwhile introduction to paleontology.

TIM T. TOKARYK

Saskatchewan Museum of Natural History, 2340 Alberta Street, Regina, Saskatchewan S4P 3V7

Three Men of the Beagle

By Richard Lee Marks. 1991. Alfred A. Knopf, New York, 256 pp., illus. U.S. $29.

The popularization of information gathered by Charles Darwin is still making its way into print. We are all familiar with Darwin's theories but are less acquainted with the specifics of his Beagle voyage.

Traveller and writer Richard Marks singles out one event of the Beagle voyage, that being the developing relationships with the Yahgans, a Tierra del Fuego tribe. Since the Beagle contact (Captained by Robert FitzRoy) was the first sustained, described intercourse that modern civilization had with this tribe, Marks sets out to put this developing relations between primitive and civilized societies in chronological order, back-lighted by social developments in England. The three men of the Beagle are Captain FitzRoy, Darwin, and Jemmy Buttons, a Vahganian.

Jemmy Buttons was part of a ecosystem that struggled daily for survival. Primarily mussel eaters, occasionally supplanted by fish or otter, these barely clad "savages", as described by Darwin, lived in a harsh coastal climate only 1000 kilometres from the Antarctic. Nomadic, preoccupied with daily survival, they had no concept of religious deities or the repulsion of killing other human life (shipwrecked sailors would inevitably die at the hands of Fuegians or by starvation). To solve this dilemma FitzRoy, at his own expense, returned to England with Jemmy Buttons (and two others) for education. A few years later the well liked Jemmy Buttons returned to his homeland able to converse somewhat in English and instructed in the new ways of civilization. Yet, anchored in his tribal ways, subsequent contacts recorded a return to a more familiar lifestyle.

One learning experience of reading Marks' book is the detail, length of description, and the mind of Fitzroy who is often left out of the historical sketches of his time. FitzRoy's compassion for the safety of his fellow sailors (he was one of the founders of modern weather forecasting), his work, and fond-

ness towards Darwin have often been overlooked or underplayed by historians. Marks' description is quite clear.

The third man of the Beagle was of course Darwin though his role in this book is the least described of the three. The relationship with FitzRoy throughout the voyage, and years later are emphasised, not so much as his discoveries and ideas. Darwin, 22 years old, boarded the Beagle with open eyes and mind, later developing into ideas and questions. FitzRoy, 26 years old, a seasoned naval captain, was in many ways a sounding board for young Darwin.

After the initial contacts with the Yahgans the three men went their separate ways. We know what was to become of Darwin. FitzRoy was to succumb to eventually living back in England, dabbling in politics, and later continuing his modifications to weather forecasting. Politicking with his peers, financial droughts, depression, were too much for him to bear. He committed suicide.

But what happened to Jemmy Buttons? The last third of the book describes how, under the guise of puritan expansion by means of establishing missionaries, continued contact eventually meant the end of the Yahgans. A population estimated at 6000, the last Yahgan died sometime in the nineteen sixties. "As extinct as the mylodon. As extinct as the moa."

Three Men of the Beagle is a hauntingly vivid tale of contact with primitive societies and the results of our encroachment. Fitzroy, Darwin and the young Yahgan, Jemmy Button, are our guides.

TIM T. TOKARYK

Saskatchewan Museum of Natural History, 2340 Albert Street, Regina, Saskatchewan S4P 3V7

NEW TITLES

Zoology

†**Aquatic invertebrates of Alberta.** 1991. By Hugh F. Clifford. University of Alberta Press, Edmonton. xii + 538 pp., illus. Cloth $82; paper $72.

†**Atlas of pelagic birds of western Canada.** 1991. By K. H. Morgan, K. Vermeer, and R. W. McKelvey. Occasional Paper Number 72, Canadian Wildlife Service. Environment Canada, Delta, British Columbia. 72 pp., illus.

***The avian ark: tails from a wild-bird hospital.** 1991. By Kitt Chubb. Douglas and McIntyre, Vancouver. ix + 157 pp., illus. $22.95.

†**Biological control by natural enemies.** 1991. By Paul Debach and David Rosen. 2nd edition. Cambridge University Press, New York. xiv + 440 pp., illus. Cloth U.S.$44.50; paper U.S.$17.95.

The Cambridge encyclopedia of ornithology. 1991. Edited by Michael Brooke and Tim Birkhead. Cambridge University Press, New York. ix + 362 pp., illus. U.S.$49.50.

Catalogue of the order Tylenchida (Nematoda). 1991. By Agriculture Canada. Canadian Communications Group, Ottawa. 195 pp. $24.95 in Canada; U.S.$29.95 elsewhere + $5.40 shipping.

***Crane music: a natural history of American cranes.** 1991. By Paul A. Johnsgard. Smithsonian Institute Press, Washington. 136 pp., illus. U.S.$19.95.

†**Environmental physiology of the amphibians.** 1992. Edited by Martin E. Feder and Warren W. Burggren. University of Chicago Press, Chicago. 712 pp., illus. Cloth U.S.$135; paper U.S.$47.50.

The freshwater fishes of Europe, volume 2: Clupeidae, Anguillidae. 1991. Edited by Henri Hoestlandt. AULA-Verlag, Wiesbaden, Germany. 448 pp., illus. DM198.

†**Key migratory bird terrestrial habitat sites in the Northwest Territories.** 1991. By S. A. Alexander, R. S. Ferguson, and K. J. McCormick. Occasional Paper Number 71, Canadian Wildlife Service. Environment Canada, Yellowknife. 184 pp., illus.

Living shells of the Caribbean and Florida Keys. 1991. By Robert E. Lipe and R. Tucker Abbott. Gallery Books, New York. 80 pp., illus. U.S.$8.95.

***Mammals of the neotropics, volume 2: the southern zone Chile, Argentina, Uruguay, Paraguay.** 1992. By Kent H. Redford and John F. Eisenberg. University of Chicago Press, Chicago. 272 pp., illus. Cloth U.S.$95; paper U.S.$39.

Manatees and dugongs. 1991. By John E. Reynolds III and Daniel K. Odell. Facts on File, New York. 208 pp., illus. U.S.$24.95; $31.95 in Canada.

Nemipterid fishes of the World. 1991. FAO species catalogue, volume 12. UNIPUB, Lanham, Maryland. 149 pp., illus. U.S.$45.

***No room for bears: a wilderness writer's experiences with a threatened breed.** 1991. By Frank Dufresne. Alaska Northwest, Bothell, Washington. illus. U.S.$12.95; $15.95 in Canada.

***Pacific Salmon life histories.** 1991. Edited by C. Groot and L. Margolis. UBC Press, Vancouver. 608 pp., illus. $65.

Probably more than you want to know about fishes of the Pacific coast. 1991. By Robin Milton Love. Really Big Press, Santa Barbara. 204 pp., illus. U.S.$12.95.

Seashells of the Northern Hemisphere. 1991. By R. Tucker Abbott. Gallery Books, New York. 176 pp., illus. U.S.$9.95.

Botany

Plant resistance to herbivores and pathogens: ecology, evolution and genetics. 1992. Edited by Robert S. Fritz and Ellen L. Simms. University of Chicago Press, Chicago. 608 pp., illus. Cloth U.S.$75; paper U.S.$29.95.

Plant biomechanics: an engineering approach to plant form and function. 1992. By Karl J. Niklas. University of Chicago Press, Chicago. 584 pp., illus. Cloth U.S.$85; paper U.S.$29.50.

The practical botanist: an essential field guide to studying, classifying, and collecting plants. 1991. By Rick Imes. Fireside Books, New York. 151 pp., illus. Cloth U.S.$24.95; paper U.S.$14.95.

Roses red, violets blue: why flowers have colors. 1991. By Sylvia A. Johnson. Lerner, Minneapolis. 64 pp., illus. U.S.$14.95.

Environment

Acidification research in the Netherlands. 1991. Edited by G. J. Heij and T. Schneider. Studies in Environmental Science Volume 46. Elsevier, New York. xiv + 772 pp. U.S.$215.50.

The butterfly garden: creating beautiful gardens to attract butterflies. 1991. Villard Books, New York. 144 pp., illus. U.S.$25.

*__A critique for ecology.__ 1991. By Robert Henry Peters. Cambridge University Press, New York. xiv + 366 pp., illus. Cloth U.S.$.79.50; paper U.S.$29.95.

*__The ecology of a garden: the first fifteen years.__ 1991. By Jennifer Owen. Cambridge University Press, New York. xii + 403 pp., illus. U.S.$100.

Environmental health. 1992. By Dade W. Moeller. Harvard University Press, Cambridge, Massachusetts. 344 pp., illus. U.S.$39.95.

Environmental Risk identification and management. 1991. By Albert R. Wilson. Lewis, Boca Raton, Florida. c336 pp., illus. U.S.$69.95 in U.S.A.; U.S.$84 elsewhere.

Evaluation of environmental data for regulatory and impact assessment. 1991. By S. Ramamoorthy and E. Baddaloo. Studies in Environmental Science Volume 41. Elsevier, New York. x + 466 pp. U.S.$154.

From Gaia to selfish genes: selected writings in the life sciences. 1991. Edited by Connie Barlow. MIT Press, Cambridge, Massachusetts. xi + 273 pp., illus. U.S.$17.50.

Handbook of radioactive contamination and decontamination. 1991. By J. Severa and J. Bar. Studies in Environmental Sciences Volume 47. Elsevier, New York. xxiv + 366 pp. U.S.$146.

Healing the planet: strategies for solving the environmental crisis. 1991. By Paul and Anne Ehrlich. Addison-Wesley, New York. xiv + 352 pp., illus. U.S.$22.95.

Highway pollution. 1991. Edited by R. S. Hamilton and R. M. Harrison. Studies in Environmental Science Volume 44. Elsevier, New York. xii + 510 pp. U.S.$166.50.

*__Human activity and the environment,__ 1991. 1991. By Statistics Canada, Ottawa. 237 pp., illus. $35 in Canada; U.S.$42 in U.S.A.; U.S.$49 elsewhere.

Natural resources: riches or remnants? 1991. Proceedings of a conference. Canadian Society of Environmental Biologists, Box 9567, Edmonton, Alberta T6E 5X2. 101 pp. $20.

Nature tourism: managing for the environment. 1991. Edited by Tensie Whelan. Island Press, Washington. xii + 223 pp., illus. Cloth U.S.$34.95; paper U.S.$19.95.

The strange world of deep-sea vents. 1991. By R. V. Fodor. Hillside, Enslow, New Jersey. 64 pp., illus. U.S.$15.95.

†__Terrestrial ecosystems through time: evolutionary paleoecology of terrestrial plants and animals.__ 1992. By Anna K. Behrensmeyer, John D. Damuth, William A. Di Micele, Richard Potts, Hans-Dieter Sues, and Scott L. Wing. University of Chicago Press, Chicago. 552 pp., illus. Cloth U.S.$75; paper U.S.$29.95.

Turning the tide: saving the Chesapeake Bay. 1991. By Tom Horton and William M. Etchbaum. Island Press, Washington. xxiv + 327 pp., illus. Cloth U.S.$22.95; paper U.S.$14.95.

Waste materials in construction. 1991. Edited by J. J. J. M. Goumans, H. A. van der Sloot, and T. Aalbers. Proceedings of a conference, Maastricht, Netherlands, 10-14 November, 1991. Studies in Environmental Science Volume 48. Elsevier, New York. xiv + 672 pp. U.S.$218.

Miscellaneous

†__Annotated correspondence, 1901-1928, of Sarah Agnes Saunders (1836-1915), William Edwin Saunders (1861-1943), and Edgar Melville Serle Dale (1883-1943) with Lewis McIver Terrill (1878-1968).__ 1991. By W. W. Judd. Phelps Publishing, London, Ontario. 104 pp. $10.

*__Carl Akeley: Africa's collector, Africa's savior.__ 1991. By Penelope Bodry-Sanders. Paragon House, New York. xii + 298 pp., illus. U.S.$19.95. [Reviewed in 106(2)].

*__Migrations: the travels of a naturalist.__ 1991. By Bobby Tulloch. McClelland and Stewart, Markham, Ontario. 151pp., illus. $44.95.

One long argument: Charles Darwin and the genesis of modern evolutionary thought. 1991. By Ernst Mayr. Harvard University Press, Cambridge, Massachusetts. xiv + 195 pp., illus. U.S.$19.95.

Books For Young Naturalists

African elephants: giants of the land. 1992. By Dorothy H. Patent. Holiday House, New York. 40 pp., illus. U.S.$14.95.

The alphabet in nature. 1991. By Judy Feldman. Children's Press, Chicago. 32 pp., illus. U.S.$17.27.

Amazing bats. 1991. By Frank Greenaway. Knopf, New York. 29 pp., illus. U.S.$6.95.

Animal communications. 1991. By Jim Flegg. Newington Press, Brookfield, Connecticut. 32 pp., illus. U.S.$11.90.

Animal communications; Animal societies. 1991. By Jeremy Cherfas. Lerner, Minneapolis. Each 32 pp., illus. Each U.S.$10.95.

The Berenstain bears don't pollute (anymore). 1991. By Stan and Jan Berenstain. Random House, New York. 32 pp., illus. U.S.$2.25.

Children's atlas of the environment. 1991. By Rand McNally, Chicago. 80 pp., illus. U.S.$14.95.

Creepy crawlies: ladybugs, lobsters, and other amazing arthropods. 1991. By London's Natural History Museum. Sterling, New York. 107 pp., illus. U.S.$14.95.

Extremely weird bats; Extremely weird frogs; and **Extremely weird spiders.** 1991. By Sarah Lovett. John Muir, Sante Fe. Each 48 pp., illus. U.S.$9.95.

Fall; Summer. 1991. By Ron Hirsch; Cobblehill, New York. 26 pp., illus. and 27 pp., illus. Each U.S.$13.95.

Flamingo; Snake. 1991. By Caroline Arnold. Morrow Junior, New York. Each 48 pp., illus. Each U.S.$13.95.

Frog; and **Duck.** 1991. By Angela Royston. Lodestar, New York. Each 22 pp., illus. U.S.$6.95.

The icky bug counting book. 1991. By Jerry Pallotta. Watertown, Charlesbridge, Massachusetts. 32 pp., illus. Cloth U.S.$14.95; paper U.S.$6.95.

In the bears' forest. 1991. By Bertill Pettersson; translated by Steven T. Murray. Rands Books, New York. 36 pp., illus. U.S.$11.95.

It could still be a bird. 1991. By Allan Fowler. Children's Press, Chicago. 31 pp., illus. U.S.$12.60.

Living lights: creatures that glow in the dark. 1991. By Michael Filisky. Crown, New York. 20 pp., illus. U.S.$15.

My first look at nature. 1991. By Dorling Kindersley. Random House, New York. 16 pp., illus. U.S.$7.

Nature by design. 1991. By Bruce Brooks. Farrar-Strauss-Giroux, New York. 74 pp., illus. U.S.$13.95.

Ocean World. 1991. By Tony Rice. Millbrook Press, Brookfield, Connecticut. 64 pp., illus. U.S.$13.90.

Red leaf, yellow leaf. 1991. By Lois Ehlert. Harcourt, Brace, Jovanovich, San Diego. 32 pp., illus. U.S.$14.95.

Secrets of a wildlife watcher. 1991. By Jim Arnosky. Beech Tree Books, New York. 80 pp., illus. U.S.$7.95.

The science book of things that grow. 1991. By Neil Ardley. Gulliver Books, San Diego. 30 pp., illus. U.S.$9.95.

Slippery babies: young frogs, toads, and salamanders. 1991. By Ginny Johnston and Judy Cutchins. Morrow Junior, New York. 40 pp., illus. U.S.$13.95.

39 easy plant biology experiments. 1991. By Robert W. Wood. TAB, Blue Ridge Summit, Pennsylvania. xi + 123 pp., illus. Cloth U.S.$16.95; paper U.S.$9.95.

Tigers with wings: the great horned owl. 1991. By Barbara Juster Esbensen. Orchard, New York., 32 pp., illus. U.S.$14.95.

The visual dictionary of animals. 1991. By Dorling Kindersley, New York. 64 pp., illus. U.S.$14.95.

Walrus: on location. 1991. By Kathy Darling. Lothrop, Lee and Shepard, New York. 40 pp., illus. U.S.$14.95.

Wasps at home. 1991. By Bianca Lavies. Dutton, New York. 32 pp., illus. U.S.$13.95.

Whales. 1991. By Gail Gibbons. Holiday House, New York. 30 pp., illus. U.S.$14.95.

Who comes to the water hole? 1991. by Colleen Stanley Bare. Cobblehill, New York. 28 pp., illus. U.S.$13.95.

Will we miss them: endangered species? 1992. By Alexandra Wright. Charlesbridge, Waterton, Massachusetts. 29 pp., illus. U.S.$14.95.

*Assigned for review
†Available for review

TABLE ON CONTENTS *(concluded)*

Prey delivered to two Cooper's Hawk, *Accipiter cooperii*, nests in northern mixed grass prairie
DANIEL J. PETERSON and ROBERT K. MURPHY 385

Growth of nestling Merlins, *Falco columbarius*
NAVJOT S. SODHI 387

Western Catalpa, *Catalpa speciosa*, colonising in Toronto, Ontario
C. S. CHURCHER 390

Do estrous female Gray Squirrels, *Sciurus carolinensis*, advertise their receptivity?
JOHN L. KOPROWSKI 392

Efficacy of three types of live traps for capturing weasels, *Mustela* spp.
JERROLD L. BELANT 394

Further range extensions of the crayfish *Orconectes rusticus* in the Lake Superior Basin of northwestern Ontario
WALTER T. MOMOT 397

Fourspine Stickleback, *Apeltes quadracus*, from a freshwater lake on the Avalon Peninsula of eastern Newfoundland
CHRISTINE E. CAMPBELL 400

Prey of the sea anemone *Stomphia didemon* (Anthozoa: Actiniaria) on the west coast of Canada
JAMES A. DALBY, JR. 403

First confirmed Canadian record of Bendire's Thrasher, *Tomostoma bendirei*
ALEXANDER MILLS 404

News and Comment

George Hazen McGee, 1909-1991 — Lousise de Kirkland Lawrence, 1894-1992 — Some external awards to members of *The Ottawa Field-Naturalists' Club* and contributors to *The Canadian Field-Naturalist* 406

Book Reviews

Zoology: Zoo The Modern Ark — The Magpies: The Ecology and Behaviour of Black-billed and Yellow-billed Magpies — Advances in the Study of *Peromyscus* (Rodentia) — Birds of the Lower Colorado — Crane Music — Ravens in Winter — Bird Trapping and Bird Banding: A Handbook for Trapping Methods All Over the World — The Secret World of Animals: Under Water — Birds and Islands: Travels in Wild Places — Migrations: Travels of a Naturalist 408

Botany: Mushrooms of North America — Fungi Without Gills (Hymenomycetes and Gasteromycetes: An Identification Handbook — A Natural History of Trees of Eastern and Central North America — A Natural History of Western Trees — Vascular Flora of the Southeastern United States: Volume 3, Part 2, Leguminosae (Fabaceae) — Vascular Plants of Minnesota, A Checklist and Atlas — The Illustrated Field Guide to Ferns and Allied Plants of the British Isles — Manual of Vascular Plants of Northeastern United States and Adjacent Canada — Common Poisonous Plants and Mushrooms of North America 414

Environment: Extinction, Bad Genes or Bad Luck? — Human Activity and the Environment 1991 — Causes of Evolution: A Paleontological Prespective — The Miner's Canary — Foundations of Ecology: Classic Papers with Commentaries — In a Patch of Fireweed 418

Miscellaneous: Pioneer Ecologist: The Life and Work of Victor Ernest Shelford 1877-1968 — Fossils: The Key to the Past — Three Men of the Beagle 422

New Titles 424

Mailing date of the previous issue 106(2) : 5 May 1993

Articles

Contributions to the Tardigrada of the Canadian High-Arctic
1. Freshwater Tardigrades from Devon Island, Northwest Territories
E. A. VAN ROMPU, W. H. DE SMET, and L. BEYENS 303

Range extension for the Plains Spadefoot, *Scaphiopus bombifrons*, inferred from owl petlets found near Outlook, Saskatchewan
RICHARD E. MORLAN and JOHN V. MATTHEWS, JR. 311

The status of selected birds in east-central Alaska
ROBERT J. RITCHIE and ROBERT E. AMBROSE 316

Habitat change as a factor in the decline of the western Canadian Logerhead Shrike, *Lanius ludovicianus*, population
EDMUND S. TELFER 321

Diet of California Bighorn Sheep, *Ovis canadensis californiana*, in British Columbia: Assessing optimal foraging habitat
BRIAN M. WIKEEM and MICHAEL D. PITT 327

Winter habitat use by male and female American Kestrels, *Falco sparverius*, in southwestern Ontario
TODD W. ARNOLD and PAMELA A. MARTIN 336

The vascular plant flora of Rankin Inlet, District of Keewatin, Northwest Territories
J. B. KOROL 342

Re-examination of a Water Birch, *Betula occidentalis*, outlier of the northwestern Hudson Bay Lowlands
PETER A. SCOTT, RICHARD A. STANIFORTH, and DAVID C. F. FAYLE 348

Notes on Short-eared Owl, *Asio flammeus*, nest sites, reproduction, and territory sizes in coastal Massachusetts
DENVER W. HOLT 352

Hunter-harvest of captive-raised male White-tailed Deer, *Odocoileus virginianus*, released in Upper Michigan
JOHN J. OZOGA, ROBERT V. DOEPKER, and RICHARD D. EARLE 357

Recovery patterns of Ospreys, *Pandion haliaetus*, banded in Canada up to 1989
PETER J. EWINS and C. STUART HOUSTON 361

Characteristics of Blackburnian Warbler, *Dendroica fusca*, breeding habitat in Upper Michigan
ROBERT V. DOEPKER, RICHARD D. EARLE, and JOHN J. OZOGA 366

Schizaea pusilla, Curly-Grass Fern, an addition to the flora of New Brunswick
JAMES P. GOLTZ and HAROLD R. HINDS 372

Concentration of migrant diving ducks at Point Pelee National Park, Ontario, in response to invasion of Zebra Mussels, *Dreissena polymorpha*
ALAN WORMINGTON and J. H. LEACH 376

Notes

Brown Bear, *Ursus arctos*, preying upon Gray Wolf, *Canis lupus*, pups at a wolf den
R. D. HAYES and A. BAER 381

Homing of relocated Raccoons, *Procyon lotor*
JERROLD L. BELANT 382

concluded on inside back cover

ISSN 0008-3550

The CANADIAN FIELD-NATURALIST

Published by THE OTTAWA FIELD-NATURALISTS' CLUB, Ottawa, Canada

Volume 106, Number 4 October-December 1992

The Ottawa Field-Naturalists' Club

FOUNDED IN 1879

Patron

His Excellency The Right Honourable Ramon John Hnatyshyn, P.C., C.C., C.M.M., Q.C.,
Governor General of Canada

The objectives of this Club shall be to promote the appreciation, preservation and conservation of Canada's natural heritage; to encourage investigation and publish the results of research in all fields of natural history and to diffuse information on these fields as widely as possible; to support and cooperate with organizations engaged in preserving, maintaining or restoring environments of high quality for living things.

Honorary Members

Edward L. Bousfield
Irwin M. Brodo
William J. Cody
Ellaine Dickson
William G. Dore
R. Yorke Edwards
Anthony J. Erskine
Clarence Frankton
Claude E. Garton
W. Earl Godfrey
C. Stuart Houston
Thomas H. Manning
Don E. McAllister
Stewart D. MacDonald
Verna Ross McGiffin
Hue N. MacKenzie
Eugene G. Munroe
Robert W. Nero
Hugh M. Raup
Loris S. Russell
Douglas B.O. Savile
Pauline Snure
Mary E. Stuart
Sheila Thomson

1992 Council

President: Frank Pope
Vice-President: Michael Murphy
Recording Secretary: Connie Clark
Corresponding Secretary: Eileen Evans
Treasurer: Gillian Marston

Ronald E. Bedford
Barry Bendell
Fenja Brodo
Steve Blight
Lee Cairnie
Martha Camfield
William J. Cody
Francis R. Cook
Don Cuddy
Ellaine Dickson
Enid Frankton
Colin Gaskell
Bill Gummer
Jeff Harrison
Jack Romanow
Doreen Watler
Ken Young

Those wishing to communicate with the Club should address correspondence to: The Ottawa Field-Naturalists' Club, Box P.O. Box 35069, Westgate P.O. Ottawa, Canada K1Z 1A2. For information on Club activities telephone (613) 722-3050.

The Canadian Field-Naturalist

The *Canadian Field-Naturalist* is published quarterly by The Ottawa Field-Naturalists' Club. Opinions and ideas expressed in this journal do not necessarily reflect those of The Ottawa Field-Naturalists' Club or any other agency.

Editor: Francis R. Cook, R.R. 3, North Augusta, Ontario K0G 1R0; 613-269-3211
Assistant to Editor: P.J. Narraway; **Copy Editor:** Wanda J. Cook
Business Manager: William J. Cody, P.O. Box 35069, Westgate P.O. Ottawa, Canada K1Z 1A2 (613) 996-1665
Book Review Editor: Dr. J. Wilson Eedy, R.R. 1, Moffat, Ontario L0P 1J0
Coordinator, *The Biological Flora of Canada*: Dr. George H. La Roi, Department of Botany, University of Alberta, Edmonton, Alberta T6G 2E9
Associate Editors:

C.D. Bird
Robert R. Campbell
Brian W. Coad
Anthony J. Erskine
W. Earl Godfrey
Diana Laubitz
William O. Pruitt, Jr.
Stephen M. Smith

Chairman, Publications Committee: Ronald E. Bedford

All manuscripts intended for publication should be addressed to the Editor at home address.

Subscriptions and Membership
Subscription rates for individuals are $23 per calendar year. Libraries and other institutions may subscribe at the rate of $38 per year (volume). The Ottawa Field-Naturalists' Club annual membership fee of $23 includes a subscription to *The Canadian Field-Naturalist.* All foreign subscribers (including USA) must add an additional $4.00 to cover postage. Subscriptions, applications for membership, notices of changes of address, and undeliverable copies should be mailed to: The Ottawa Field-Naturalists' Club, P.O. Box 35069, Westgate P.O. Ottawa, Canada K1Z 1A2.
Second Class Mail Registration No. 0527 – Return Postage Guaranteed. Date of this issue:October-December 1992 (January 1994).

Back Numbers and Index
Most back numbers of this journal and its predecessors, Transactions of The Ottawa Field-Naturalists' Club, 1879-1886, and The Ottawa Naturalist, 1887-1919, and Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: The Thread-leaved Sundew, *Drosera filiformis*, at Swaine's Road Bog, Shelburne County, Nova Scotia. Photograph courtesy of Bill Freedman, Dalhousie University. See article by B. Freedman, W. Maass, and P. Parfenov, pages 534-542.

The Canadian Field-Naturalist

Volume 106, Number 4 October–December 1992

Distribution, Abundance, and Changes of Seabird Populations of the Gaspé Peninsula, Québec, 1979 to 1989

Gilles Chapdelaine and Pierre Brousseau

Canadian Wildlife Service, P. O. Box 10100, Ste-Foy, Québec G1V 4H5

Chapdelaine, Gilles, and Pierre Brousseau. 1992. Distribution, abundance, and changes of seabird population of the Gaspé Peninsula, Québec, 1979 to 1989. Canadian Field-Naturalist 106(4): 427–434.

Censuses conducted around the Gaspé Peninsula in 1979 and 1989 revealed 13 species of breeding seabirds, comprising about 230300 adults. The Northern Gannet (*Sula bassanus*), Black-legged Kittiwake (*Rissa tridactyla*) and Common Murre (*Uria aalge*) made up 82% of the total; the remainder included Leach's Storm-Petrel (*Oceanodroma leucorhoa*), Great Cormorant (*Phalacrocorax carbo*), Double-crested Cormorant (*Phalacrocorax auritus*), Ring-billed Gull (*Larus delawarensis*), Herring Gull (*Larus argentatus*), Great Black-backed Gull (*Larus marinus*), Common Tern (*Sterna hirundo*), Razorbill (*Alca torda*), Black Guillemot (*Cepphus grylle*) and Atlantic Puffin (*Fratercula arctica*). Except for the Herring Gull, all species increased in numbers between 1979 and 1989, a general tendency observed elsewhere in the Gulf of St. Lawrence.

Les inventaires réalisés autour de la péninsule gaspésienne en 1979 et 1989 ont révélé la nidification de 13 espèces d'oiseaux marins dont les effectifs totaux s'élèvent à plus de 230 300 individus adultes. Le Fou de Bassan (Sula bassanus), la Mouette tridactyle (Rissa tridactyla), et la Marmette de Troïl (Uria aalge) représentent plus de 82% des effectifs. Le reste est représenté par le Pétrel cul-blanc (Oceanodroma leucorhoa), le Grand Cormoran (Phalacrocorax carbo), le Cormoran à aigrettes (Phalacrocorax auritus), le Goéland à bec cerclé (Larus delawarensis), le Goéland argenté (Larus argentatus), le Goéland à manteau noir (Larus marinus), la Sterne pierregarin (Sterna hirundo), le Petit Pingouin (Alca torda), le Guillemot à miroir (Cepphus grylle) et le Macareux moine (Fratercula arctica). À l'exception du Goéland argenté, toutes les espèces ont connu un accroissement de leurs effectifs respectifs entre 1979 et 1989. Cette tendance générale s'insère dans l'augmentation observée ailleurs dans le golfe du Saint-Laurent.

Key Words: Seabirds, population, Gaspé Peninsula, Bonaventure Island, Forillon National Park, Laridae, Alcidae.

Seabird populations of the Gaspé Peninsula are particularly well known because of their presence at Bonaventure Island, Federal Migratory Bird Sanctuary and Provincial Park, and Forillon National Park, two very popular summer tourist sites (see Figure 1). Apart from general reviews of some breeding colonies by Ball (1938) and Wynne-Edwards (1954), and certain species-specific accounts on Northern Gannet at Bonaventure Island (Taverner 1918; Poulin 1968; Nettleship 1975; Chapdelaine *et al.* 1987) and Double-crested Cormorant (Desgranges *et al.* 1984), there is no study that provides a detailed description of the populations of colonially-breeding seabirds around the Gaspé Peninsula. Thus the principal purpose of this paper is to report distribution levels of abundance and changes of these seabird populations between 1979 and 1989.

Methods

All the information reported here comes from censuses carried out by the Canadian Wildlife Service during June and early July in 1979 and 1989. Counting techniques varied according to species and colony, but were applied in an identical manner at each individual location in both years. A summary of the methods used for each species follows.

Leach's Storm-Petrel *Oceanodroma leucorhoa.*

Systematic counts of active burrows were made at Bonaventure Island, the only known breeding site. A burrow was considered active if there were recent signs of excavation at the entry of the burrow entrance and if an oily smell, characteristic of the Leach's Storm-Petrel, was detected.

Northern Gannet *Sula bassanus.*

Population analysis from aerial photography was

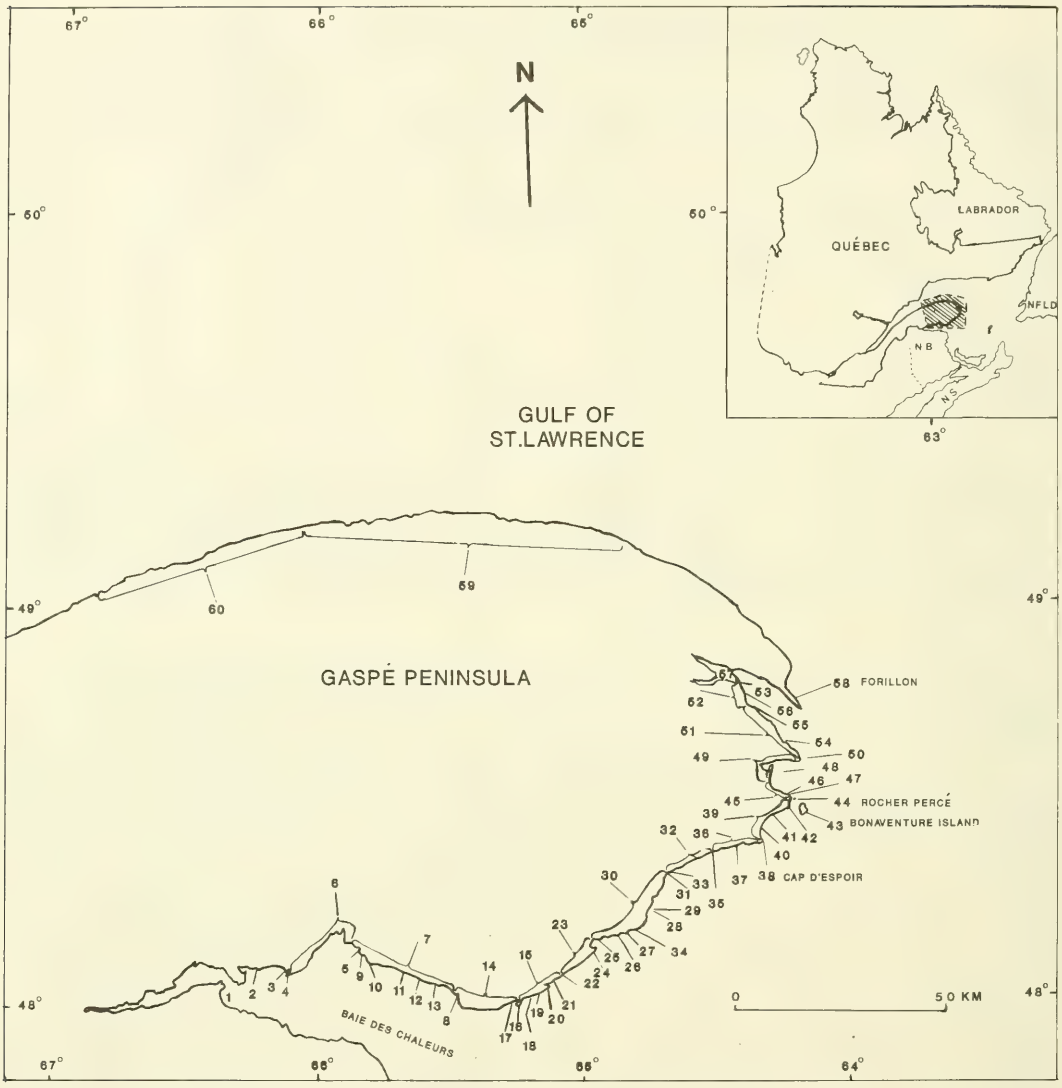


FIGURE 1. Locations of seabird population between Miguaha (1) and Îlot Mahy Sud (28). See Table 1 for location listing and coordinates.

used at Bonaventure Island in both years employing similar techniques. A series of photographs of the entire colony was taken from a fixed-wing aircraft using a Hasselblad camera (120 mm lens, PXP 120 black-and-white film) in 1979 and a 6x7 Pentax camera (105 mm lens, PXP 220 black-and-white film) in 1989. The photographs were of high quality in both years and yielded comparable colony mosaics. Counts of birds were made on 20x20 cm photos enlargements using a stereoscope and a semi-automatic dot counter. The unit of measurement used for these counts was the number of birds present at one nest or one breeding pair (for further details on the technique, *see* Nettleship 1975, 1976a, Nettleship and Chapdelaine 1988).

Great Cormorant *Phalacrocorax carbo* and Double-crested Cormorant *P. auritus*.

The Great Cormorant only breeds at Rocher Percé where nests were counted from a boat. Nests at Double-crested Cormorant colonies were also counted directly from a boat except for those on the upper plateau of Rocher Percé which were counted from the Mont Sainte-Anne lookout, just behind Percé village.

Ring-billed Gull *Larus delawarensis*.

This species breeds in very small numbers at two

locations on waste wood generated by the Chandler paper-mill and at the Sandy Beach sandspit. All nests present at the two sites were systematically counted.

Herring Gull *Larus argentatus* and **Great Black-backed Gull *L. marinus*.**

All Herring Gull colonies accessible by land (sandspits and islands) were visited in both years. Systematic counts of nests and contents (number of eggs) were made. Where the two species nested together we calculated the ratio of the number of birds belonging to each species and applied that ratio to the number of gull nests counted. Where nests were on sea-cliffs, they were counted from a boat. The colony on the upper plateau of Rocher Percé was counted from the Mont Sainte-Anne lookout.

Common Eider *Somateria mollissima.*

Few Common Eider colonies occur around the Gaspé Peninsula. Counts of nests present on the Mahy Islands and Plate Island.

Black-legged Kittiwake *Rissa tridactyla.*

The largest colony was on Bonaventure Island. It was counted from aerial photographs obtained during the Northern Gannet survey (see above). Nests at other colonies in Chaleur Bay and at the tip of the Gaspé Peninsula were counted from a boat.

Common Tern *Sterna hirundo.*

All colonies were accessible by land. Ground counts of nests and nest contents (number of eggs) were made.

Common Murre *Uria aalge* and **Razorbill *Alca torda.***

Bonaventure Island was the only known Common Murre breeding site. Murres were most abundant on the northeast side of the island where counting the breeding birds on the rock ledges from the land is difficult owing to the absence of suitable observation points. Counts of murres on ledges were therefore made from a boat. A conversion factor of 0.76 (k = Np/Ni, where Np = number of pairs and Ni = number of birds) was used in both years to convert the number of birds counted into pairs (*see* Nettleship 1976b for details of 'k'). The estimates for population size are considered to be minimum values and only moderately accurate owing to the small number of daily counts made on the absence of a value for 'k' for 1989. Razorbills were also difficult to survey and census. Counts of individual birds were made and expressed in individuals rather than breeding pairs due to the absence of a suitable 'k'-value for this species at Bonaventure Island.

Black Guillemot *Cepphus grylle.*

The distribution of Black Guillemot colonies is closely associated with the presence of cliffs all round the peninsula. Counts were made of birds on the cliffs and on the water at the base of the cliffs at all colonies. The time the counts were conducted was recorded in order to use conversion factors established previously at Cap d'Espoir (Cairns 1979). Although the accuracy of this approach is limited, it can be used to determine inter-year differences within an order of magnitude (*see* Nettleship and Birkhead 1985).

Atlantic Puffin *Fratercula arctica.*

The Atlantic Puffin nested only on Bonaventure Island and in small numbers. No actual sightings were made but puffins were reported through the 1989 season by visiting birders. In 1979 puffins were seen in very small numbers during the census period.

Non-colonial breeders

Some seabird species also breed solitary or in very small groups, particularly the Herring Gull, Great Black-backed Gull and Black Guillemot. Distribution information for these particular cases has been presented by shoreline sector (see Table 2).

In an attempt to express the rate at which changes occured for each species, a calculation of the compound annual growth rate (r) was made according to the formula $r = (\log_e N(t) - \log_e N(0))t^{-1}$, where N(t) = population size at time t, N(0) = population size at time 0 and t = number of years between two censuses (*see* Ricklefs 1973 for details).

Results and Discussion

Species composition, distribution and abundance

The species diversity of the Gaspé Peninsula seabird community increased from 12 to 13 between 1979 and 1989 with the addition of the Ring-billed Gull (table 1-3). In 1989, three species comprised 82.5% of the total population of 230 342 adults: Black-legged Kittiwake (37.4%), Common Murre (24.2%) and Northern Gannet (20.9%). The Black-legged Kittiwake was distributed in 13 colonies, whereas the Common Murre and Northern Gannet were found at only one colony, Bonaventure Island. Four other species had a wider distribution and accounted for 15% of the combined population: the Herring Gull (6.7%) was found in 17 colonies and 9 sectors, the Double-crested Cormorant (4.1%) in 29 colonies, the Black Guillemot (2.7%) in 4 colonies and 13 sectors, and the Great Black-backed Gull (1.5%) in 14 colonies and 6 sectors. The remaining six species were usually present in very small numbers with very restricted distributions making up 2.5% of the total population. The Common Tern (2.0%) was found in six colonies, Razorbill (0.2%) in four, Common Eider (0.1%) in three, Ring-billed Gull (0.1%) in two and Great Cormorant (0.1%) in one. Leach's Storm-Petrel and Atlantic Puffin (0.1%) were found at Bonaventure Island.

Table 1 Distribution, species composition and changes in population size of seabirds breeding between Miguasha and Îlot Mahy Sud on the Gaspé Peninsula, Québec, 1979 to 1989. (Population size is given in pairs except for Razorbill. Numbers in parentheses by site/sector name correspond with locations shown in Figure 1).

COLONIES	COORDINATES	Double-Crested Cormorant		Herring Gull		Great Black-backed Gull		Black-legged Kittiwake		Common Tern		Black Guillemot	
		1979	1989	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989
Miguasha to St-Omer (1)	48°04'N,66°18'W 48°07'N,66°13'W			1									
St-Omer (2)	48°07'N,66°13'W			209	495	2	62				133		
Banc de Carleton (3)	48°07'N,66°07'W			40	136	2	27			390	841		
Île au Pique-nique (4)	48°06'N,66°07'W			175	29	17	62						
Île Taylor (5)	48°08'N,65°52'W				202		27				318		
New Richmond to Bonaventure (7)	48°03'N,65°52'W 48°03'N,65°49'W			527	506	3						31	68
Îlots de la rivière Bonaventure (8)	48°03'N,65°29'W				12								
Pointe Howatson (9)	48°08'N,65°49'W	5	11										
Caps Noirs (10)	48°08'N,65°47'W	363	415										
Caplan (11)	48°05'N,65°39'W	134	62						22				
Ruisseau Leblanc (12)	48°05'N,65°37'W		152										
Marais de Saint-Siméon (13)	48°04'N,65°28'W											36	
Bonaventure to Paspébiac (14)	48°04'N,65°29'W 48°02'N,65°15'W			487	482	1	3					91	62
Paspébiac to Shigawake (15)	48°02'N,65°15'W 48°06'N,65°03'W			589	797	1	20					13	54
Marais de Paspébiac (16)	48°02'N,65°15'W				231		21						
Paspébiac-Ouest (17)	48°01'N,65°16'W	224	622										
Pointe aux Corbeaux (18)	48°02'N,65°13'W	52	106										
Pointe Huntington (19)	48°02'N,65°12'W	34	24										
Pointe à Ritchie (20)	48°02'N,65°09'W	88	281						56				
Saint-Godefroi (21)	48°04'N,65°05'W	177	246						405				
Shigawake (22)	48°06'N,65°03'W		17										
Shigawake to Port-Daniel (23)	48°06'N,65°03'W 48°21'N,64°41'W			233	483	4	1					159	230
Colline Daniel (24)	48°08'N,64°58'W	25	7						15				
Pointe Pillar (25)	48°12'N,64°56'W	116	173					13	324				
Gascons-Ouest (26)	48°11'N,64°53'W	27	18										
Pointe Reddish (27)	48°11'N,64°52'W		3						202				
Îlot Mahy sud (28)	48°15'N,64°45'W	58	353		142		94						
All Sites/sectors combined		1303	2490	2261	3485	30	317	13	1024	390	1328	294	414

Population trends

Between 1979 and 1989 increases were recorded for 11 of 12 species; only the Herring Gull showed a decline (Table 4). Data for the Atlantic Puffin are too few to conclude for a change. It is impossible to give detailed analyses of species' population trends or the cause and effect relationships. Too little is known of basic biological parameters including productivity, food habits, prey abundance, chick growth and survival rates. Changes recorded between 1979 and 1989 are probably not equally accurate for all species. Those which can be censused with good accuracy are Black-legged Kittiwake, Northern Gannet, Great Cormorant, Double-crested

Table 2. Distribution, species composition and changes in population size of seabirds breeding between Îlot Mahy Nord and Forillon on the Gaspé Peninsula, Québec, 1979 to 1989. (Population size is given in pairs except for Razorbill. Numbers in parentheses by site/sector name correspond with locations shown in Figure 1).

COLONIES	COORDINATES	Double-Crested Cormorant		Common Elder		Ring-billed Gull		Herring Gull		Great Black backed Gull		Black-legged Kittiwake		Common Tern		Razorbill		Black Guillenot	
		1979	1989	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989
Îlot Mahy nord (29)	48°15'N,64°45'W		233	1	23			3360	836	54	358								
Chandler (31)	48°21'N,64°41'W						15	586	108		3				217				
Chandler to	48°21'N,64°41'W																		
Grande-Rivière (32)	48°24'N,64°30'W							4											
Île Dupuis (33)	48°20'N,64°40'W	161	60					480	20		8								
Anse à Pierre Loiselle (34)	48°12'N,64°48'W							70					18						
Grande-Rivière (35)	48°24'N,64°30'W												301						
Grande-Rivière to	48°24'N,64°30'W																		
Cap d'Espoir (36)	48°26'N,64°19'W							251	365		15							87	79
Sainte-Thérèse (37)	48°24'N,64°24'W		145									45	135						
Cap d'Espoir to	48°26'N,64°19'W																		
Percé (39)	48°32'N,64°13'W							386	624									72	96
Cap Malin (40)	48°27'N,64°19'W		2																
Weygan (41)	48°29'N,64°17'W		10							3	6								
Cap Blanc (42)	48°30'N,64°13'W		15										45				2		
Percé to	48°32'N,64°13'W																		
Cannes de Roches (45)	48°33'N,64°17'W								91		5							121	107
Trois Soeurs (46)	48°32'N,64°13'W											420	1774				6		
Cap Barré (47)	48°32'N,64°13'W							37	5										
Barachois de Malbaie (48)	48°35'N,64°14'W							66	210		28								
Coin du Banc to	48°34'N,64°18'W																		
Pointe St-Pierre (49)	48°38'N,64°11'W							3										41	230
Île Plate (50)	48°38'N,64°18'W	35	142	35	102			755	525	2	166								
Pointe St-Pierre to	48°38'N,64°11'W																		
Douglastown (51)	48°46'N,64°23'W							239	352		6					228	495		
Douglastown to	48°46'N,64°23'W																		
Sandy Beach (52)	48°49'N,64°24'W							42	87									7	59
Sandy Beach (53)	48°49'N,64°24'W				3		6	+	488	+	241			69	862				
Grande Anse (54)	48°41'N,64°14'W		75																
Bois Brûlé (55)	48°46'N,64°22'W	12	210																
Cap Haldimand (56)	48°48'N,64°22'W	198	183																
Gaspé (57)	48°50'N,64°28'W		158																
Cloridorme to	49°11'N,64°50'W																		
Marsoui (59)	49°13'N,66°04'W								21									511	474
Marsoui to	49°13'N,66°04'W																		
Baie des Capucins (60)	49°02'N,66°51'W																	+	107
All Sites/sectors combined		406	1233	36	128		21	6279	3732	89	836	465	2273	69	1079		8	1067	1647

Table 3. Principal seabird colonies on the Gaspé Peninsula and changes in population sizes, 1979 to 1989 (in pairs except for Razorbill and Atlantic Puffin which are individual birds).

SPECIES	Cap d'Espoir (38)		Bonaventure Island (43)		Rocher Percé (44)		Forillon Penisula (58)		Total	
	1979	1989	1979	1989	1979	1989	1979	1989	1979	1989
Leach's Storm-Petrel			10	21					10	21
Northern Gannet			18 245	24 125					18 245	24 125
Great Cormorant					16	35			16	35
Double-crested Cormorant	29	98			467	474	238	371	734	943
Common Eider							10	+	10	+
Herring Gull	64	167	+	137	595	250	593	429	1 252	983
Great Black-backed Gull		12	11	37	50	123	9	12	70	184
Black-legged Kittiwake	1 899	4 492	15 647	23 650	16	1 387	3 807	10 597	21 369	40 126
Common Murre			11 866	27 857					11 866	27 857
Razorbill	2	2	307	552	3	27	40	45	352	626
Black Guillemot	33	23	75	101	64	72	475	794	647	990
Atlantic Puffin			5	+					5	+

Cormorant, Common Eider, Ring-billed Gull, Herring Gull, Great Black-backed Gull and Common Tern. Caution is required in respect of the compound growth rates calculated for the Alcids shown in table 4 because of the wide daily variation of number of birds attending at colonies and the few k values derived to estimate breeding pairs. Nevertheless, a few comments specific to certain species may help us understand some increases and changes in their respective distributions.

The Bonaventure Island Northern Gannet population is currently maintaining a compound annual growth of 3.1%. At that rate, the population should exceed 30 000 pairs by the year 2000. Historical data show that the species' numbers grew between the end of the last century and the late 1960s, rising from 1500 to 20 500 pairs. Then from 1970 to 1976 a population decline set in which was closely associated with a low-hatching rate probably caused by heavy organochlorine contamination (Nettleship 1975, 1976a; Chapdelaine et al. 1987; Nettleship and Chapdelaine 1988). Since 1979, annual productivity has fluctuated between 78 and 89%, which normally should result in a population increase (Chapdelaine et al. 1987, and G. Chapdelaine, unpublished data).

Table 4. Changes in population sizes in the Gaspé Peninsula, 1979 to 1989 (in pairs, except for Razorbill which is individual birds).

Species	Year of survey		Compound annual growth (%)
	1979	1989	
Leach's Storm-Petrel	10	21	8.5
Northern Gannet	18 245	24 125	3.1
Great Cormorant	16	35	9.0
Double-crested Cormorant	2 443	4 666	7.4
Common Eider	36	128	15.1
Herring Gull	9 792	8 200	-1.9
Great Black-backed Gull	187	1 337	24.4
Black-legged Kittiwake	21 847	43 423	7.9
Common Tern	459	2 407	20.2
Common Murre	11 866	27 857	9.7
Razorbill	352	634	6.7
Black Guillemot	2 008	3 051	4.7

The Double-crested Cormorant population increase between 1979 and 1989 is reflected in the addition of 10 new colonies to the 19 that existed in 1979. The average compound annual growth rate was 7.4%. This is below the 10.8% growth rate reported by Bédard (1988. Gestion des populations de Cormorans à aigrettes dans l'estuaire du Sainte-Laurent, Québec. 89 pages.) for all St. Lawrence Estuary Double-crested Cormorant colonies between 1979 and 1987 and the 22.4% rate cited for sanctuary populations on the north shore of the St. Lawrence between 1982 and 1988 (Chapdelaine and Brousseau 1991). The majority of Gaspé Pensinsula colonies are found on sea-cliffs that, in several places, are unstable and subject to erosion. This is particularly true of colonies located in the Chaleur Bay and Bay of Gaspé area. The five colonies that decreased are located on unstable cliffs, a condition that may have forced the birds to relocate at other colonies or even establish new ones. Thus, the pronounced increases in colony size such at Paspébiac-Ouest and the Mahy Islands may be due to immigration rather their own productivity. It is equally possible that emigration to other St. Lawrence sectors such as the Estuary and

the north shore may have occurred. Such movements would explain the high growth rates recorded there compared with those for the Gaspé Peninsula, although supporting evidence is limited.

The distribution and abundance of the Black-legged Kittiwake, the most abundant breeding species on the Gaspé peninsula, has been described in detail for the Gulf of St. Lawrence by Chapdelaine and Brousseau 1989. A 5% average compound annual growth rate was recorded between 1974 and 1985 for the Gulf as a whole. The growth rate for the Gaspé Peninsula population was established at 7.9% between 1979 and 1989 (Table 4). However, there was a drop in the growth rate of the largest colony, Bonaventure Island, which accounts for 55% of the total population on the peninsula. This colony had 23 544 pairs in 1985 (Chapdelaine and Brousseau 1989) compared with 23 650 in 1989, which represents an annual growth rate of nearly zero. It seems that the Bonaventure Island breeding habitat is fully occupied, not only owing to the increase in numbers of kittiwakes, but also because of the increases in Northern Gannets and Common Murres which use cliff ledges for breeding. The limitation of nesting space for kittiwakes at Bonaventure may explain the appearance of new colonies round the peninsula between 1979 and 1989.

Two species stand out their rapid growth: the Great Black-backed Gull and Common Tern, with mean annual growth rates of 24.4 and 20.2%, respectively (Table 4). Large increases in Great Black-backed Gull numbers occurred, particularly on the Mahy Islands and Plate Island (Table 1). The Common Tern increase was reflected not only in growth at traditional colonies (Banc de Carleton and Sandy Beach) but also by the establishment of four new colonies since 1979 (Table 1 and 2). The magnitude of these increases suggest that immigration was involved, but the birds' origins are unknown.

The Common Murre, Razorbill and Black Guillemot showed growth rates of 9.7, 6.7, and 4.7%, respectively. The increase of Common Murres on Bonaventure Island corresponds closely with those recorded for the sanctuaries on the north shore of the Gulf of St. Lawrence, where annual growth between 1977 and 1988 was about 10% (Chapdelaine and Brousseau 1991).

The general increase of the seabird population on the Gaspé Peninsula suggests an increase in the supply of forage fish such as Sandlance (*Ammodytes spp.*) and Capelin (*Mallotus villosus*) in the waters of the Gulf of St. Lawrence. Changes in fish abundance may be related to the recorded decrease in the number of large predators, especially the Atlantic Cod (*Gadus morhua*) (Bureau de la statistique du Québec, 1977-1987). As a result, it is therefore possible that a surplus of food has been created through the overfishing of cod, a supply that is now available to certain seabird species. Chapdelaine and Brousseau (1989) suggested this as a possible explanation for the increase in Black-legged Kittiwake numbers throughout the Gulf of St.Lawrence and the overall growth of the seabird population on the north shore (Chapdelaine and Brousseau 1991). Similar events have been reported elsewhere, e.g. the North Sea (Furness 1984). However, fisheries and seabird data are too scanty to demonstrate a causal relationship. Thus, even though systematic seabird monitoring efforts provide much information about changes in population size and status within large geographic regions or ecosystems, they do little to help identify the factors responsible for the changes observed.

Acknowledgments

Thanks are due to André Bourget for much assistance on the field work. We would like also express many thanks to M. Bernard Major of Ministère du Loisir, de la Chasse et de la Pêche, for having arranged our cruise to Bonaventure Island. C. A. Drolet improved the manuscript and provided valuable suggestions.

Literature Cited

Ball, S. C. 1938. Summer birds of the Forillon, Gaspe County, Quebec. Canadian Field-Naturalist 52: 95–122.

Cairns, D. 1979. Censusing hole-nesting Auks by visual counts. Bird-Banding 50: 358–364.

Chapdelaine, G., P. Laporte and **D. N. Nettleship.** 1987. Population, productivity, and DDT contamination of Northern Gannets at Bonaventure Island, Quebec, 1967-1984. Canadian Journal of Zoology 65: 2922–2926.

Chapdelaine, G. et **P. Brousseau.** 1989. Size and trends of Black-legged Kittiwake (*Rissa tridactyla*) populations in the Gulf of St. Lawrence (Quebec) 1974-1985. American Birds 43: 21–24.

Chapdelaine, G. and **P. Brousseau.** 1991. Thirteenth census of seabird populations in the sanctuaries of the North Shore of the Gulf of St. Lawrence. Canadian Field-Naturalist 105: 60–66.

DesGranges, J. L., G. Chapdelaine, et **P. Dupuis.** 1984. Sites de nidification et dynamique des populations du Cormoran à aigrettes au Québec. Canadian Journal of Zoology 62: 1260–1267.

Furness, R. W. 1984. Seabird-fisheries relationships in the northeast Atlantic and North Sea. Pages 162-169 *in* Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships. *Edited by* D. N. Nettleship. G. A. Sanger and P.F. Springer. Canadian Wildlife Service Special Publication, Ottawa.

Nettleship, D. N. 1975. A recent decline of Gannets, *Morus bassanus*, on Bonaventure Island, Quebec. Canadian Field-Naturalist 89: 125–133.

Nettleship, D. N. 1976a. Gannets in North America: present numbers and recent changes. Wilson Bulletin 88: 300–313.

Nettleship, D. N. 1976b. Census techniques for seabirds of arctic and eastern Canada. Canadian Wildlife Service. Occasional Paper Number 23. 33 pages.

Nettleship, D. N., and **T. R. Birkhead.** 1985. The Atlantic Alcidae. Academic Press, Orlando. 574 pages.

Nettleship, D. N. and **G. Chapdelaine.** 1988. Population size and status of the Northern Gannet *Sula bassanus* in North America, 1984. Journal of Field of Ornithology 59: 120–127.

Poulin, J.-M. 1968. Reproduction du Fou de Bassan (*Sula bassana*) Île Bonaventure (Québec). Thèse de Maîtrise, Université Laval, Québec, Province de Québec. 110 pages.

Ricklefs, R. E. 1973. Ecology. Chiron Press, Portland. 861 pages.

Taverner, P. A. 1918. The gannets of Bonaventure Island. Ottawa Naturalist 32: 21–26.

Wynne-Edwards, V. C. 1954. Sea-birds of Percé and the Gaspé Peninsula, Province of Québec 4th. Mercury Press, Montréal. 34 pages.

Received 29 January 1992
Accepted 25 March 1993

Application of a Double-count Aerial Survey Technique for White-tailed Deer, *Odocoileus virginianus,* on Anticosti Island, Québec

François Potvin[1], Laurier Breton[1], Louis-Paul Rivest[2], and André Gingras[3]

[1]Ministère du Loisir, de la Chasse et de la Pêche, 150 René-Lévesque E. (5e), Québec, Québec G1R 4Y1
[2]Département de Mathématiques et de Statistique, Université Laval, Cité Universitaire, Québec G1K 7P4
[3]Ministère du Loisir, de la Chasse et de la Pêche, 818 avenue Laure, Sept-Îles, Québec G4R 1Y8

Potvin, François, Laurier Breton, Louis-Paul Rivest, and André Gingras. 1992. Application of a double-count aerial survey technique for White-tailed Deer, *Odocoileus virginianus,* on Anticosti Island, Québec. Canadian Field-Naturalist 106(4): 435–442.

We applied a double-count aerial survey technique over six surveys conducted during two winters and two summers on Anticosti Island, Québec. A total of 2532 White-tailed Deer (*Odocoileus virginianus*) belonging to 2046 groups was counted inside 704 0.36-km^2 strip plots (6 km x 60 m) by two independent observers located on the same side of a helicopter. Deer groups were classified according to activity (moving or not), forest cover (open or closed), and position relative to the aircraft (under or beside). The sighting probabilities of the groups were computed using the model underlying the Petersen estimate. Sighting probabilities were 0.56 for single deer and 0.81 for groups of two or more deer. Single deer were more visible when moving or located in the open. As compared with a conventional single-count aerial survey, the double-count technique increased the estimated deer number by 35% (uncorrected) due to the second observer and by 58% when corrected by the Petersen model. A corrected deer estimate was derived for single deer and groups of two or more deer, separately, and the total deer population was obtained by summing those two values. The estimated density varied between 8.2 ± 0.98 and 20.6 ± 1.79 deer/km^2 ($\bar{x}$ ± SE), depending on the survey.

Nous avons appliqué la technique du double inventaire aérien lors de six inventaires réalisés durant deux hivers et deux étés sur l'île d'Anticosti, Québec. Au total, 2532 cerfs de Virginie (*Odocoileus virginianus*) appartenant à 2046 groupes furent comptés à l'intérieur de 704 parcelles de 0.36 km^2 (6 km x 60 m) par deux observateurs indépendants placés du même côté de l'hélicoptère. Les groupes de cerfs furent classés selon leur activité (en mouvement ou non), le couvert forestier (ouvert ou fermé) et leur position par rapport à l'aéronef (au-dessous ou à côté). La probabilité de visibilité des groupes fut calculée selon le modèle d'estimation de Petersen. La probabilité de visibilité fut de 0.56 pour les cerfs solitaires et de 0.81 pour les groupes de deux animaux ou plus. Les cerfs solitaires les plus visibles étaient ceux en mouvement ou à découvert. Par rapport à un inventaire simple conventionnel, la technique du double inventaire a permis d'accroître l'estimation du nombre de cerfs de 35% (sans facteur de correction) par l'ajout d'un deuxième observateur et de 58% en appliquant un facteur de correction d'après le modèle de Petersen. Nous avons réalisé une estimation séparée pour les cerfs solitaires et les groupes de deux cerfs ou plus, en additionnant ces deux valeurs pour obtenir la population totale. Selon l'inventaire, la densité estimée varie de 8.2 ± 0.98 à 20.6± 1.79 cerfs/km^2.

Key Words: White-tailed Deer, *Odocoileus virginianus*, Anticosti Island, Québec, aerial survey, visibility bias, Petersen estimate, double count, helicopter.

Although reasonable trend estimates may be sufficient for managing large mammals extensively, accurate and precise density values are necessary for intensive management. Aerial surveys are frequently the only practical approach to censusing large and inaccessible areas for species such as Moose (*Alces alces*) (Crête et al. 1986; Gasaway and Dubois 1987). Aerial surveys for deer (*Odocoileus* spp.) are currently used over shrub vegetation in Texas (Beasom 1979; Beasom et al. 1981), Pinyon Pine (*Pinus edulis*) — juniper (*Juniperus osteosperma*) forests in Colorado (Kufeld et al. 1980; Bartmann 1983) and mixed conifer-deciduous forests in Minnesota (Floyd et al. 1979; Nelson and Mech 1986; Fuller 1990). These techniques have not been applied to the boreal forest because of its closed coniferous canopy.

Aerial surveys are biased because sighting probabilities rates are often no better than 50-75% (Caughley 1974; Bartmann et al. 1986), if not less (Beasom et al. 1986). Visibility bias can be caused by type of aircraft, speed, altitude and strip width (Caughley 1974; Caughley et al. 1976; Beasom et al. 1981; Bayliss and Giles 1985; Shupe and Beasom 1987; DeYoung et al. 1989). Observer ability, fatigue and boredom can influence the results (Dirschl et al. 1981). Visibility depends also on animal activity (Crête et al. 1986; Samuel et al. 1987; Ackerman 1988), group size and composition (Tärnhuvud 1986; Samuel et al. 1987; Ackerman 1988). Finally, sighting probabilities can be affected by vegetation cover and topography (Tärnhuvud 1986; Samuel et al. 1987; Ackerman 1988; Bayliss and Yeomans 1989), temperature (Bayliss and Giles

1985), and snow on the ground or on tree crowns (Crête et al. 1986; Tärnhuvud 1986).

Pollock and Kendall (1987) and Steinhorst and Samuel (1989) reviewed techniques for evaluating and correcting visibility bias. The ideal approach would provide a sighting probability for each survey and each animal category, thereby accounting for a combination of technical conditions, observer performance, animal behavior, and area characteristics peculiar to a given survey. The line-transect technique provides such an estimate of the sighting probability and has recently been tested in relatively open areas for Mule Deer (*Odocoileus hemionus*) in Colorado (White et al. 1989) and White-tailed Deer (*O. virginianus*) in Texas (DeYoung et al. 1989). Another approach has been a double count by two independent observers. In this technique, two surveys are conducted and each object (or animal group) must be identified as either seen by one or both observers; a corrected density estimate is derived based on the Petersen estimator or another appropriate statistic. Results for the double count can come from two separate surveys, either ground, aerial or both, such as used by Henny et al. (1974) and Henny and Anderson (1979) on Osprey (*Pandion haliaetus*) nests, Magnuson et al. (1978) on crocodile (*Crocodylus porosus*) nests, Crête (1979) on Moose, and Estes and Jameson (1988) on Sea Otters (*Enhydra lutris*). This technique has also been applied to aerial surveys with two observers counting simultaneously in the same aircraft: Cook and Jacobsen (1979) and Fuller (1990) on White-tailed Deer, Grier et al. (1981) on Bald Eagle (*Haliaeetus leucocephalus*) nests, Caughley and Grice (1982) on Emus (*Dromaius novaehollandiae*), Bayliss and Yeomans (1989) and Graham and Bell (1989) on feral livestock, Johnson et al. (1989) on Mottled Duck (*Anas fulvigula*), and Marsh and Sinclair (1989) on aquatic fauna.

During two winters and two summers, we applied a double-count technique involving two independant observers in the same aircraft counting deer inside strip plots on Anticosti Island. Our objective was to adapt this technique for estimating deer numbers on large tracts of boreal forest. We measured the sighting probabilities of deer under a variety of conditions, and compared single-count with double-count estimates of deer numbers.

Study Area and Methods

Anticosti (49°30'N, 63°00'W) is a large island (7943 km^2) located in the Gulf of Saint Lawrence. It has a rather flat topography and an average elevation of 126 m. The boreal forest is dominated by White Spruce (*Picea glauca*), Balsam Fir (*Abies balsamea*), and Black Spruce (*P. mariana*). Deciduous species, mostly Trembling Aspen (*Populus tremuloides*) and White Birch (*Betula papyrifera*), are distributed sporadically. Forest logging, fires, and insect epidemics have affected more than one third of the area in the last 35 years. As a result, crown closure varies from 0 to almost 90% depending on the stage of the forest. Large open bogs are common, especially in the eastern portion. The climate is sub-boreal with a maritime influence, characterized by cool summers and relatively mild winters. Snow is present on the ground for six months and its depth exceeds 50 cm for 72 days on average.

Deer were counted by two observers located on the left side of a Bell 206-B helicopter. A bubble window installed in the back door enabled the rear observer to see under and beside the aircraft. The front observer took advantage of the front upper and side windows and of the chin window on the floor. The strip width extended on the left side only from 0° (below the helicopter) to a 45° angle from the vertical. The outer boundary was delimited by aligning two reference points, one on the side window (plastic tape) and one on a rod extending outside and perpendicular to the aircraft. Before each survey, the helicopter followed a straight line (road, airstrip) so that both observers verified that their viewing angles were the same.

The navigator sat in the back seat behind the pilot and also had a bubble window to provide front and lateral vision. He was responsible for discriminating and recording the deer groups seen by both observers. In order to assure independence between the observers individually with the navigator, two communication systems were used. The front observer, navigator, and pilot were connected to the system of the aircraft while the rear observer was in contact with the navigator through a portable system. The earphones of the navigator were modified in such a way that the right ear was connected to the helicopter system and the left ear to the portable one. Moreover, a switch enabled the navigator to speak separately to either observer.

Strip plots 6-km long were distributed on 1:50 000 maps along parallel north-south lines, either at random (first year) or systematically (second year). The Loran-C navigation system (Patric et al. 1988, Boer et al. 1989) was used to keep the heading. The front observer had a copy of the maps to locate the position of the aircraft when changing line. The navigator indicated to the crew the beginning and the end of the plots along the line. He took note of the time elapsed, to evaluate the speed, and of the altimeter reading at one point in each plot located exactly on a topographic contour line on the map, to determine the altitude above the ground. The pilot tried to maintain a speed of 60-70 km/hour, at an altitude of 60 m.

Because of the 45° viewing angle, the width of the strip was equal to the altitude. For each survey, the mean area per plot was estimated as follows:

$$AR = \frac{6 \times AL}{1000},$$

where

AR = area of a plot (km^2),
AL = mean altitude (m) over all plots surveyed.

A study area contained L plots, where:

$$L = \frac{\text{Study area size } (km^2)}{AR};$$

l of these plots were surveyed, and f (l/L) was the sampling fraction.

Sampled units were deer groups. Deer groups encountered during surveys were classified according to activity (moving or not), forest cover (first year: in the forest or in the open; second year: under a tree crown or not), and position relative to the aircraft (under or beside) (during the first year only). The navigator recorded deer sightings separately for each observer. Even when they saw a group long in advance, observers reported it only at the moment the helicopter was perpendicular to it, to help determine animals seen in common. In case of doubt, the navigator asked more details from both observers. Groups that had moved before the passage of the helicopter were recorded as initially seen in the strip by the observer. Groups located outside the strip but near to it were reported but not tallied. When observers counted a different number of deer in one group, the highest value was selected and applied to both observers.

Let h=1,..., H, and i=1,...,l denote the subscripts representing the group size and the parcel sampled, respectively. The following notation is used:

l = the number of parcels sampled,
n_{ihk} = the number of animals belonging to group size h seen by observer 1 only (k=1), by observer 2 only (k=2) or by both observers (k=3) in parcel i,
$n_{.hk}$ = the sum of the n_{ihk}'s for the l parcels sampled,
$n_{ih.}$ = the total number of animals belonging to group size h seen in the ith parcel sampled ($n_{ih.} = n_{ih1}+n_{ih2}+n_{ih3.}$),
$n_{.h.}$ = the total number of animals belonging to group size h seen in the l parcels surveyed.

For sighting probabilities, we considered three group sizes: single deer, groups of two, and groups of three or more. Sighting probabilities were computed according to a Petersen estimate (Magnuson et al. 1978) for each group size and for each observer by activity, forest cover, and position relative to the aircraft:

$$p_{h1} = \frac{n_{.h3}}{n_{.h2} + n_{.h3}}, \quad \text{and} \quad p_{h2} = \frac{n_{.h3}}{n_{.h1} + n_{.h3}},$$

where

p_{h1} = sighting probability of the front observer,
p_{h2} = sighting probability of the rear observer.

An estimate of the total population of deer T and its variance was computed according to Rivest et al. (1993). This estimate uses two correction factors for the deer missed by the observers. There is one correction factor for single deer and one for groups of two deer and more since groups of more than one deer were found to have the same visibility. The correction factor is defined as 1 over the probability that a deer, or a group of deer, is seen by at least one observer. Thus for groups of h deer, h=1,2, the correction factor is given by:

$$c_h = \frac{1}{1-(1-p_{h1})(1-p_{h2})} = 1 + \frac{n_{.h1}n_{.h2}}{n_{.h.}\, n_{.h3}}$$

where $n_{.h.}=n_{.h1}+n_{.h2}+n_{.h3}$. Rivest et al. (1993) show that redefining c_h as

$$c_h = 1 + \frac{n_{.h1}n_{.h2}}{n_{.h.}(n_{.h3}+1)}$$

reduces the bias of the correction factor. The large sample variance of c_h appears in Graham and Bell (1989)

$$v(c_h) = \frac{n_{.h2}n_{.h1}(n_{.h.}-n_{.h1})(n_{.h.}-n_{.h2})(n_{.h.}-n_{.h3})}{n^3_{.h.}\, n^3_{.h3}}.$$

When estimating correction factors for groups of more than one deer, the group, not the deer, is the experimental unit. Thus, for the above formula to yield an unbiased estimate, the n_{ihk}'s should be taken as group frequencies. Taking the n_{ihk}'s animal frequencies will underestimate the true variance for the correction factor of groups of more than one deer. This problem is minor since $v(c_1)$ is the most important variance in the formula for v(T). Rivest et al. (1993) proposed an alternative variance estimator that has less bias in small samples:

$$v(c_h) = \frac{n_{.h2}^2\, n_{.h1}^2}{n_{.h.}^2\,(n_{.h3}+1)^2} - \frac{n_{.h2}(n_{.h2}-1)n_{.h1}(n_{.h1}-1)}{n_{.h.}(n_{.h.}-1)(n_{.h3}+1)(n_{.h3}+2)}.$$

An estimate of the total number of deer in the survey area is given by:

$$T = \frac{c_1 n_{.1.}}{f} + \frac{c_2 n_{.2.}}{f}.$$

The variance of T can be written in terms of $v(c_1)$, $v(c_2)$, and $N_i=c_1n_{i1.}+c_2n_{i2.}$, the estimated number of deer in parcel i, for i=1,...,l. When f, the sampling fraction, is small (say, less than 10%), one has

$$v(T) = \frac{L^2}{l(l-1)} \sum_{i=1}^{l} (N^i - \bar{N})^2 + \frac{n_{..1}^2 v(c_1)}{f^2} + \frac{n_{..2}^2 v(c_2)}{f^2}$$

where $\bar{N} = \sum N_i/l$. The properties of this variance estimator are discussed in Rivest et al. (*in press*).

We applied the double-count technique on Anticosti Island over six surveys: (1) 5 forest blocks (160-225 km^2) during winter 1988; (2) 6 hunting territories (426-828 km^2) during summer 1988; (3) 1 forest block (160 km^2) and (4) 1 hunting territory (434 km^2) during winter 1989; the central portion of the island (4163 km^2), both in winter (5) and in summer (6), 1989. Cover types varied from closed forest to very open areas (bogs, forests totally killed by insect epidemics, cutovers).

Results

A total of 2532 deer belonging to 2046 groups was counted in 704 plots over the six surveys. Single animals (81% of the groups) and groups of two (15%) were most frequently encountered. Combining all data, sighting probability was 0.56 for single deer, 0.80 for groups of 2 deer, and 0.86 for groups of 3 or more deer (Table 1). Single deer were more difficult to see in all surveys except during winter 1989, when the sighting probability of single deer by the front observer was similar (Chi square test, $P > 0.10$) to groups of two deer. The front observer saw a higher proportion of single deer, while the rear observer was more successful with larger groups because of the better rearward vision.

Single deer were more visible for both observers when moving or located in the open (Table 2). The visibility rate of motionless single deer was generally below 0.50 as compared to 0.60-0.70 for moving animals. Single deer were more difficult to see when located in the forest or under a tree crown. Activity or cover had no effect ($P > 0.10$) for groups of two deer in most surveys, but the sample size was small for the categories motionless or under cover. Position relative to the aircraft influenced the visibility rate of the front observer in winter 1988 and of the rear observer (single deer only) in the summer of the same year.

Since our purpose was to correct the visibility bias, we compared uncorrected deer estimates (single count and double count) with that provided by the Petersen model (Table 3). Over the six surveys, the uncorrected count was increased by 35% when we added the animals detected by the front observer only to those of the rear observer. Applying the Petersen estimate further increased the population estimate by another 23%. The increase from a single

TABLE 1. Sighting probabilities (p) of groups of White-tailed Deer by two independent observers (front, rear) on Anticosti Island, Québec, according to the group size.

Survey	Period	Group size	n groups	p Front		p Rear	
1	Winter 1988	1	280	0.55		0.59	
		2	84	0.73		0.83	A[a]
		3+	41	0.91		0.84	A
2	Summer 1988	1	548	0.64		0.59	
		2	102	0.90	A	0.87	A
		3+	13	0.91	A	0.83	A
3	Winter 1989	1	232	0.47	A	0.39	
		2	22	0.50	A,B	0.83	A
		3+	3	1.00	B	1.00	A
4	Winter 1989	1	112	0.56	A	0.46	A
		2	6	0.67	A	1.00	B
		3+	2	1.00	A	1.00	A,B
5	Winter 1989	1	209	0.65	A	0.54	
		2	33	0.73	A	0.73	A
		3+	7	0.71	A	1.00	A
6	Summer 1989	1	281	0.54	A	0.58	
		2	55	0.72	B	0.81	A
		3+	16	0.67	A,B	0.91	A
All surveys		1	1 662	0.58		0.54	
		2	302	0.77	A	0.83	A
		3+	82	0.85	A	0.87	A

[a]For each survey and each observer, sighting probabilities sharing the same letter are not different (P>0.10), Chi-square test.

TABLE 2. Sighting probabilities (p) of groups of deer by two independent observers (front, rear) on Anticosti Island, Québec, according to the activity, the immediate forest cover, and the position relative to the aircraft.

Survey	Period	Group size	Activity	n groups	p Front	p Rear	Cover	n groups	p Front	p Rear	Position	n groups	p Front	p Rear
1	Winter 1988	1	Motionless	104	0.48 A[a]	0.38	Forest	247	0.51	0.60 A	Beside	228	0.59	0.59 A
			Moving	176	0.58 A	0.72	Open	33	0.95	0.56 A	Below	52	0.37	0.58 A
		2	Motionless	23	0.72 A	0.72 A	Forest	77	0.70	0.81 A	Beside	60	0.84	0.83 A
			Moving	61	0.73 A	0.87 A	Open	7	1.00	1.00 A	Below	24	0.46	0.83 A
2	Summer 1988	1	Motionless	156	0.52	0.40	Forest	320	0.56	0.52	Beside	451	0.63 A	0.67
			Moving	392	0.68	0.66	Open	228	0.74	0.67	Below	97	0.71 A	0.29
		2	Motionless	15	0.80 A	0.62	Forest	56	0.88 A	0.88 A	Beside	90	0.89 A	0.89 A
			Moving	87	0.91 A	0.91	Open	46	0.93 A	0.86 A	Below	12	1.00 A	0.75 A
3	Winter 1989	1	Motionless	112	0.29	0.18	No crown	173	0.50	0.50				
			Moving	120	0.57	0.57	Crown	59	0.24	0.09				
		2	Motionless	11	0.44 A	0.67 A	No crown	17	0.50 A	0.89 A				
			Moving	11	0.55 A	1.00 A	Crown	5	0.50 A	0.67 A				
4	Winter 1989	1	Motionless	46	0.53 A	0.27	No crown	90	0.60	0.57				
			Moving	66	0.57 A	0.62	Crown	22	0.17	0.06				
		2	Motionless	0	–	–	No crown	6	0.67	1.00				
			Moving	6	0.67	1.00	Crown	0	–	–				
5	Winter 1989	1	Motionless	74	0.45	0.27	No crown	168	0.67 A	0.65				
			Moving	135	0.71	0.68	Crown	41	0.45 A	0.14				
		2	Motionless	7	0.50 A	0.40 A	No crown	30	0.75 A	0.75 A				
			Moving	26	0.77 A	0.81 A	Crown	3	0.50 A	0.50 A				
6	Summer 1989	1	Motionless	102	0.44	0.40	No crown	267	0.55	0.60				
			Moving	179	0.59	0.68	Crown	14	0.14	0.13				
		2	Motionless	14	0.78 A	0.58	No crown	54	0.72	0.83				
			Moving	41	0.71 A	0.90	Crown	1	–	–				
All surveys		1	Motionless	594	0.45	0.33	Forest	567	0.54	0.55	Beside	679	0.62 A	0.64
			Moving	1,068	0.63	0.66	Open	261	0.76	0.65	Below	149	0.53 A	0.35
							No crown	698	0.58	0.59				
							Crown	136	0.27	0.10				
		2	Motionless	70	0.68 A	0.63	Forest	133	0.78	0.84 A	Beside	150	0.87	0.87 A
			Moving	232	0.79 A	0.89	Open	53	0.94	0.88 A	Below	36	0.61	0.79 A
							No crown	107	0.69 A	0.82				
							Crown	9	0.50 A	0.50				

[a] For each survey and each observer, sighting probabilities sharing the same letter are not significantly different (P>0.10), Chi-square test.

count to a corrected double count was more substantial for the three surveys conducted during winter 1989, when it reached about 100%. The estimated density computed by the double-count technique (corrected) varied between 8.2 ± 0.98 and 20.6 ± 1.79 deer/km^2 ($\bar{x}$ ± SE), depending on the survey.

Discussion

Sighting probabilities reported for Mule or White-tailed deer are generally below 60-70% (DeYoung 1985; Bartman et al. 1986; Beasom et al. 1986; Nelson and Mech 1986; DeYoung et al. 1989; Fuller 1990). On Anticosti Island, individual observers saw 64% of all deer and 81% of the groups of two or more deer. This appears very high considering the closed canopy of boreal forest. Surveys reported from Colorado and Texas are done at lower altitude (15-30 m) and with wider strips (generally 100-200 m). Apparently, using a narrow plot (60 m wide at 60 m altitude) allowed observers to have a very high sighting probability in Anticosti surveys.

To verify if our sighting probabilities might have been overestimated, we must consider four assumptions that are paramount for the Petersen estimate (Otis et al. 1978; Seber 1982, chapter 3):

1. Population is closed during the time between the two samples;
2. Animals do not lose their marks during the time between the two samples;
3. All marks are correctly noted and recorded;
4. Each animal has the same probability of capture in the first sample, marking does not affect the catchability of an animal and the second sample is a simple random sample.

The first assumption is readily met in our double-count technique, because both observers see deer almost at the same moment. Some deer are flushed out of the strip by the noise of the aircraft and may not be available to the rear observer. In our study, those animals were counted by the front observer if they were located inside the strip before the passage of the helicopter. This lowered the sighting probability of the rear observer but caused no bias on the corrected estimate. The front observer and the navigator very rarely saw a deer coming into the strip from outside and, in such a case, this animal was rejected.

Assumptions two and three are linked together. In this case, marking refers to making a unique observation of a group; this deer group must be recorded as either seen in common or only by the front or rear observer. Using two separate communication systems between the navigator and the observers enabled discrimination of groups. On Anticosti Island, deer were distributed rather uniformly in summer and in winter. Observations were usually separated enough in time so that no confusion arose. Criteria used to describe a group (size, movement, cover, position, sex or age group in summer, etc.) were helpful in discriminating between groups in those few cases where animals were close together.

The main problems of the double-count technique with two independent observers are with the fourth assumption. Animals have unequal catchability (i.e., probability of being sighted), and marking and recapturing are not independent because both observers have the same vantage point (Caughley and Grice 1982; Pollock and Kendall 1987). Our results clearly indicate that some animals are more difficult to see. Making separate estimates for different group categories takes this into account and is definitely better than pooling all animals together. But even then, we have no proof that within each category those deer seen represented an unbiased sample. For example, either observer occasionally reported a deer under a tree crown; however, the observer may have seen only those animals that were easier to detect in this category. Simulations have shown the technique to be robust to unequal capture probability (Magnuson et al. 1978), unless the sighting probability is below 0.45 (Caughley and Grice 1982). Graham and Bell (1989) suggested applying double surveys only to highly visible (≥0.50) populations. Bartmann et al. (1987) recommended marking >45% of the animals in small populations when using the Petersen estimate with collared Mule Deer in aerial surveys. To avoid severe bias, surveys should not be conducted when a large fraction of the deer have a low sighting probability. Such was the case during winter 1989 when, due to difficult snow conditions, 22% of the single deer sighted were under a tree crown and had a sighting probability often below 0.20.

Marsh and Sinclair (1989) have discussed the problem of availability bias in aerial surveys of aquatic fauna, e.g., water turbidity may completely hide an animal. The same concept applies to large mammals; deer hidden under large coniferous tree crowns are not available to the observer. The Petersen estimate can only correct for the perception bias of animals available. Fuller (1990) has used telemetry to obtain a minimum estimate of the proportion of deer not observable. We had no such data and must accept the fact that our population estimates may be negatively biased, especially in winter 1989. Populations exceeding 10 deer/km^2 are common in many regions on a local basis, with a mean figure of at least 3 deer/km^2 of inhabitated range in 1978 in Canada and United States (Hesselton and Hesselton 1982). Densities computed on Anticosti by the double-count technique appear exceptionally high for that latitude, which suggests that the negative bias must be small.

Group size and, for single deer, activity and forest cover affected sighting probability on Anticosti Island. Larger groups and active animals are easier to

TABLE 3. Deer numbers estimated by a single-count and the double-count technique on Anticosti Island, Québec, and deer density estimated by the double-count technique.

Survey	Period	n plots	Total deer number in the plots			Deer/km²
			Single count[a]	Double count uncorrected[b]	Double count corrected[c]	
1	Winter 1988	158	462	581	654 ± 14[d]	10.0 ± 0.73[e]
2	Summer 1988	215	591	792	891 ± 16	11.0 ± 0.66
3	Winter 1989	120	183	286	400 ± 25	10.4 ± 0.93
4	Winter 1989	61	88	132	166 ± 11	8.2 ± 0.98
5	Winter 1989	75	208	297	342 ± 11	12.3 ± 1.56
6	Summer 1989	75	346	444	518 ± 15	20.6 ± 1.79
All surveys		704	1 878	2 532	2 971 ± 36	11.6 ± 0.40

[a]Rear observer only.
[b]Front and rear observers.
[c]Petersen estimate for two group sizes (single deer and groups of two or more deer).
[d]SE of the Petersen estimate computed according to Seber (1982: 60).
[e]SE of deer density computed according to Rivest et al. (1993).

detect (Crête et al. 1986; Samuel et al. 1987; Ackerman 1988; Estes and Jameson 1988; Graham and Bell 1989; Fuller 1990). Closed canopy cover and vegetation type have a significant impact on sighting probability of wild cervids (Samuel et al. 1987; Ackerman 1988) and feral livestock (Bayliss and Yeomans 1989). Since deer behavior can change from day to day, our technique provides a good way to take into account that source of variability, as well as comparing areas having very different forest cover.

In a conventional single-count survey, two rear observers each search one side of the helicopter. We can use the results from just the rear observer to compute if there is any gain by having an additional observer in front. As compared with a single-count survey (rear observer only), the double count is more accurate (35% increase in deer number), even when no correction factor is applied (Table 3). This clearly justifies the extra manpower needed for a second observer in front. The Petersen model enables one to correct the visibility bias for available animals that may be missed by both observers. We recommend its use because it provided higher deer estimates (+23%) probably nearer to the real values than uncorrected double counts. Because sighting probabilities were different for single deer and larger groups, we also recommend that a corrected estimate be derived for these two categories separately, and that the total deer population be obtained by summing these two values. For single deer, the estimate could also be made separately according to activity or forest cover, if any of those variables significantly affects the visibility rate of both observers.

Acknowledgments

We thank R. Thériault and G. A. Laprise for field work, R. Pagé, R. Robert, J. Valentine and J. P. Ouellet for their skill with the helicopter, H. Crépault and G. Daigle for data analysis, and Société des Établissements de Plein Air du Québec (SEPAQ) for financial assistance. B. B. Ackerman, R. M. Bartmann, C. A. DeYoung, M. Crête, R. Courtois and an anonymous referee made valuable comments on previous versions of the manuscript.

Literature Cited

Ackerman, B. B. 1988. Visibility bias of mule deer aerial census procedures in southeast Idaho. Ph.D. thesis, University of Idaho

Bartmann, R. M. 1983. Appraisal for a quadrat census for mule deer in pinyon - juniper vegetation. Colorado Division of Wildlife and Game Information Leaflet 109.

Bartmann, R. M., L. H. Carpenter, R. A. Garrot, and **D. C. Bowden.** 1986. Accuracy of helicopter counts of mule deer in pinyon-juniper woodland. Wildlife Society Bulletin 14: 356–363.

Bartmann, R. M., G. C. White, L. H. Carpenter, and **R. A. Garrott.** 1987. Aerial mark-recapture estimates of confined mule deer in pinyon-juniper woodland. Journal of Wildlife Management 51: 41–46.

Bayliss, P., and **J. Giles.** 1985. Factors affecting the visibility of kangaroos counted during aerial surveys. Journal of Wildlife Management 49: 686–692.

Bayliss, P., and **K. M. Yeomans.** 1989. Correcting bias in aerial survey population estimates of feral livestock in northern Australia using the double count technique. Journal of Applied Ecology 26: 924–934.

Beasom, S. L. 1979. Precision in helicopter censusing of white-tailed deer. Journal of Wildlife Management 43: 777–780.

Beasom, S. L., J. C. Hood, and **J. R. Cain.** 1981. The effect of strip width on helicopter censusing of deer. Journal of Range Management 34: 36–37.

Beasom, S. L., F. G. Leon III, and **D. R. Synatzske.** 1986. Accuracy and precision of counting white-tailed deer with helicopters at different sampling intensities. Wildlife Society Bulletin 14: 364–368.

Boer, A. H., G. Redmond, and **T. J. Pettigrew.** 1989. Loran-C: a navigation aid for aerial surveys. Journal of Wildlife Management 53: 228–230.

Caughley, G. 1974. Bias in aerial survey. Journal of Wildlife Management 38: 921–933.

Caughley, G. 1977. Sampling in aerial survey. Journal of Wildlife Management 41: 605–615.

Caughley, G., and **D. Grice.** 1982. A correction factor for counting emus from the air and its application to counts in Western Australia. Australian Wildlife Research 9: 253–259.

Caughley, G., R. Sinclair, and **D. Scott-Kemmis.** 1976. Experiments in aerial survey. Journal of Wildlife Management 40: 290–300.

Cochran, W. G. 1977. Sampling techniques. John Wiley and Sons, New York, New York..

Cook, R. D., and **J. O. Jacobsen.** 1979. A design for estimating visibility bias in aerial surveys. Biometrics 37: 735–742.

Crête, M. 1979. Estimation de la densité d'orignaux au moyen d'inventaires aériens incomplets. Naturaliste canadien 106: 481–483.

Crête, M., L.-P. Rivest, H. Jolicoeur, J. M. Brassard, and **F. Messier.** 1986. Predicting and correcting helicopter counts of moose with observations made from fixed-wing aircraft in southern Québec. Journal of Applied Ecology 23: 751–761.

DeYoung, C. A. 1985. Accuracy of helicopter surveys of deer in south Texas. Wildlife Society Bulletin 13: 146–149.

DeYoung, C. A., F. S. Guthery, S. L. Beasom, S. P. Coughlin, and **J. R. Heffelfinger.** 1989. Improving estimates of white-tailed deer abundance from helicopter surveys. Wildlife Society Bulletin 17: 275–279.

Dirschl, H. J., M. Norton-Griffiths, and **S. P. Wetmore.** 1981. Training observers for aerial surveys of herbivores. Wildlife Society Bulletin 9: 108–115.

Estes, J. A., and **R. J. Jameson.** 1988. A double-survey estimate for sighting probability of sea otters in California. Journal of Wildlife Management 52: 70–76.

Floyd, T. J., L. D. Mech, and **M. E. Nelson.** 1979. An improved method of censusing deer in deciduous-coniferous forests. Journal of Wildlife Management 43: 258–261.

Fuller, T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildlife Monograph 110.

Gasaway, W. C., and **S. D. Dubois.** 1987. Estimating moose population parameters. Swedish Wildlife Research Supplement 1: 603–617.

Graham, A., and **R. Bell.** 1989. Investigating observer bias in aerial survey by simultaneous double-counts. Journal of Wildlife Management 53: 1009–1016

Grier, J. W., J. M. Gerrard, G. D. Hamilton, and **P. A. Gray.** 1981. Aerial-visibility bias and survey techniques for nesting bald eagles in northwestern Ontario. Journal of Wildlife Management 45: 83–92.

Henny, C. J., and **D. Anderson.** 1979. Osprey distribution, abundance, and status in western North America. III. The Baja California and Gulf of California population. Bulletin of the Southern California Academy of Sciences 78: 89–106.

Henny, C. J., M. M. Smith, and **V. D. Scotts.** 1974. The 1973 distribution and abundance of breeding ospreys in the Chesapeake Bay. Chesapeake Science 15: 125–133.

Hesselton, W. T., and **R. M. Hesselton.** 1982. White-tailed deer. Pages 878-901 *in* Wild mammals of North America: biology, management, and economics. *Edited by* J. A. Chapman, and G. A. Feldhamer. John Hopkins University Press, Baltimore.

Johnson, F. A., K. H. Pollock, and **F. Montalbano, III.** 1989. Visibility bias in aerial surveys of mottled ducks. Wildlife Society Bulletin 17: 222–227.

Magnusson, W. E., G. J. Caughley, and **G. C. Grigg.** 1978. A double-survey estimate of population size from incomplete counts. Journal of Wildlife Management 42: 174–176.

Marsh, H., and **D.F. Sinclair.** 1989. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. Journal of Wildlife Management 53: 1017–1024.

Nelson, M. E., and **L. D. Mech.** 1986. Deer population in the Central Superior National Forest, 1967-1985. U.S. Department of Agriculture, Forest Service Research Paper NC-271. 8 pages.

Otis, D. L., K. P. Burnham, G. C. White, and **D. R. Anderson.** 1978. Statistical inference from capture data on closed animal populations. Wildlife Monograph 62.

Pollock, K. H., and **W. L. Kendall.** 1987. Visibility bias in aerial surveys: a review of estimation procedures. Journal of Wildlife Management 51: 502–510.

Rivest, L. P., F. Potvin, H. Crépeau, and **G. Daigle.** *in press.* Statistical methods for aerial surveys using the double-count technique to correct visibility bias. Biometrics.

Samuel, M. D., E. O. Garton, M. W. Schelgel, and **R. G. Carson.** 1987. Visibility bias during surveys of elk in north central Idaho. Journal of Wildlife Management 51: 622–630.

Seber, G. A. F. 1982. The estimation of population abundance. Second edition. Charles Griffin, London. 654 pages.

Shupe, T. E., and **S. L. Beason.** 1987. Speed and attitude influences on helicopter surveys of mammals in brushland. Wildlife Society Bulletin 15: 552–555.

Steinhorst, R. K., and **M. D. Samuel.** 1989. Sightability adjustment methods for aerial surveys of wildlife populations. Biometrics 45: 415–425.

Tärnhuvud, T. 1986. Development of moose survey methods - Aerial surveys. Swedish Agriculture University, Uppsala.

White, G. C., R. M. Bartmann, L. H. Carpenter, and **R. A. Garrott.** 1989. Evaluation of aerial line transects for estimating mule deer densities. Journal of Wildlife Management 53: 625–635.

Received 18 October 1991
Accepted 17 June 1993

Responses of Breeding Bald Eagles, *Haliaeetus leucocephalis,* to Human Activities in Northcentral Michigan

Teryl G. Grubb[1], William W. Bowerman[2], John P. Giesy[2], and Gary A. Dawson[3]

[1]USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 2500 S. Pine Knoll Drive, Flagstaff, Arizona 86001

[2]Department of Fisheries and Wildlife, Pesticide Research Center, Institute for Environmental Toxicology, Michigan State University, East Lansing, Michigan 48824

[3]Environmental Department, Consumers Power Company, 1945 W. Parnall Road, Jackson, Michigan 49201

Grubb, Teryl G., William W. Bowerman, John P. Giesy, and Gary A. Dawson. 1992. Responses of breeding Bald Eagles, *Haliaeetus leucocephalus,* to human activities in northcentral Michigan. Canadian Field-Naturalist 106(4): 443–453.

To characterize disturbance and analyze eagle response, we recorded 714 events of potentially disturbing human activity near six pairs of Bald Eagles (*Haliaeetus leucocephalus*) breeding in northcentral Michigan in 1990. Vehicles and pedestrians elicited the highest response frequencies, but aircraft and aquatic activities were the most common. Magnitude of response was inversely proportional to median distance-to-disturbance. Seventy-five percent of all alert and flight responses occurred when activity was within 500 m and 200 m, respectively. Adults responded more frequently than nestlings, and at greater distances-to-disturbance when perched away from nests. May was the peak month for human activity, most of which occurred on weekends (60%) and after noon (72%). Classification tree (CART) models are used to assess disturbance-specific response frequencies and to formulate management considerations.

Key Words: Bald Eagle, *Haliaeetus leucocephalus*, human disturbance, behaviour, breeding, classification trees, modeling, management, Michigan.

Interactions between humans and Bald Eagles (*Haliaeetus leucocephalus*) during the breeding season occur throughout most of the eagle's range and can be detrimental to reproductive success (Fyfe and Olendorff 1976; Fraser 1985). Different-sized protection zones and regulation of human activity around occupied nest sites have been used as management techniques by the USDA Forest Service and other agencies to decrease the potential for disturbance to nesting eagles (Mathisen 1968; Grier et al. 1983). However, specific data on the types, characteristics, and effects of potentially disturbing human activities in the vicinity of breeding Bald Eagles in Michigan were lacking. To evaluate human-Bald Eagle interactions in the northern Lower Peninsula of Michigan, we measured and analyzed human activities and associated eagle response at six breeding areas.

We also compared our results with disturbance studies from several other populations and regions, particularly recent Arizona research (Grubb and King 1991), which the present work replicates in many respects. In the context of ever-increasing disturbance of wildlife communities, every community cannot be studied individually. There is a need for clear, predictive models or other management tools that broadly apply beyond the local scale. Through an assessment of similarities and differences exhibited by the Michigan and Arizona populations, we develop a broader perspective on the management application of our disturbance findings.

Study Area

The study area was located in the northern Lower Peninsula of Michigan along the Au Sable River in Alcona, Iosco, Oscoda, and Otsego counties and the Manistee River in Manistee County. Four sites were on dam ponds created by hydro-electric facilities. Five breeding areas were in the Huron-Manistee National Forest, while the sixth was on private land within 1.6 km of the U.S. Army Air National Guard, Camp Grayling artillery and bombing range. Terrain was flat to rolling with occasional hills and an elevational range of 200 to 400 m. Vegetation was predominantly continuous mixed forest consisting of White (*Pinus strobus*), Red (*P. resinosa*), and Jack pine (*P. banksiana*). Aspen (*Populus grandidentata* and *P. tremuloides*), oak (*Quercus rubra* and *Q. alba*), maple (*Acer rubrum* and *A. saccharum*) and Paper Birch (*Betula papyrifera*) were common hardwood species. The area was rural and sparsely populated but supported recreational activity all year.

Methods

Using the nest watch procedures of Forbis et al. (1985) and Grubb and King (1991), we recorded potentially disturbing human activities within 2000 m of potentially affected eagles at four breeding areas on the Au Sable River and two on the Manistee River during March-June 1990. Observations were made from locations typically 400-600 m from nests with good views of the surrounding vicinity and fre-

TABLE 1. Disturbance and response characteristics for 714 events of potentially disturbing human activity within 2000 m of breeding Bald Eagles in northcentral Michigan, 1990.

	Disturbance				No Response		Response	
Group/ Type	Frequency (no. of events)	Median no. per event	Median distance (m)	Median duration (min)	Frequency (%)[a]	Median distance (m)	Frequency (%)[a]	Median distance (m)
Vehicle	**55**	**1.0**	**250**	**5.0**	**26**	**1000**	**74**	**250**
ATVs	24	2.5	500	3.0	29	1000	71	500
Autos	31	1.0	200	5.0	23	1500	77	200
Pedestrian	**29**	**1.0**	**250**	**6.0**	**55**	**250**	**45**	**185**
Hikers	24	1.0	250	7.0	62	250	38	250
Anglers	5	1.0	60	1.0	20	300	80	45
Aquatic	**239**	**1.0**	**110**	**2.0**	**54**	**150**	**46**	**100**
Boats	218	1.0	110	1.5	52	150	48	100
Canoes	21	3.0	300	3.0	76	350	24	50
Noise	**50**	**4.0**	**850**	**2.0**	**62**	**1000**	**38**	**500**
Gunshots	25	4.0	500	1.0	24	600	76	500
Artillery	25	7.0	1500	6.0	100	1500	0	–
Aircraft[b]	**341**	**2.0**	**800**	**10.0**	**71**	**800**	**29**	**500**
Jets	241	2.0	800	12.0	68	800	31	500
Light planes	52	1.0	1125	2.0	85	1425	15	800
Helicopters	48	1.0	700	4.5	71	750	29	700
Totals	**714**	**1.0**	**400**	**4.0**	**60**	**700**	**40**	**300**
Arizona Totals[c]	**4188**	**1.0**	**500**	**1.0**	**60**	**700**	**40**	**300**

[a] Response frequency (%) = response sample size divided by number of events x 100%.
[b] Aircraft figures strongly influenced by proximity of military air base near one breeding area (N = 282, *see* Table 2).
[c] From 13 breeding areas, 1983-1985 (Grubb and King 1991). Within-group response frequencies were 52% vehicle, 72% pedestrian, 53% aquatic, 54% noise, and 33% aircraft.

quently used perches. Binoculars (7-10X) and spotting scopes (15-60X) aided viewing. Nest watchers were deployed in pairs for safety and to facilitate data collection/recording. To increase standardization and strengthen within- and between-site comparisons, standard sample days (two weekdays and two weekend days every two weeks) were designated for dawn-to-dusk data collection at all nest sites.

Eleven types of human activity in five potential disturbance groups (vehicle, pedestrian, aquatic, noise, aircraft; Table 1) were identified. Aquatic is defined as water-based recreational activity. Within groups, "boats" refers to powered craft and "canoes" includes kayaks. "ATVs" includes motorcycles and personal all-terrain vehicles; "autos" indicates cars, jeeps, and trucks. Noise includes gunshots and distant artillery, which were sudden, often loud, and usually sound only. Distances for noise were only recorded when the source was known.

Our dependent variables for assessing disturbance were the type (none, alert = noticeably agitated, and flight) and severity (frequency or percent) of response (Grubb and King 1991). For each disturbance group, we determined frequency of occurrence (F_N) and frequency of response (F_R), then calculated relative occurrence (O_R), within-group response (R_G), and overall response (R_O) as follows:

$$O_R = \frac{F_N}{\Sigma(F_N)},$$

$$R_G = \frac{F_R}{F_N}, \text{ and}$$

$$R_O = \frac{(R_G \times F_N)}{\Sigma(F_R)} \text{ or } \frac{F_R}{\Sigma(F_R)}.$$

For percentages the above figures were multiplied by 100. For CART modeling (see below) and some analyses of frequency and distance, response was treated as none/any (any = alert + flight).

We recorded distance-from-affected-eagle-to-disturbance, duration-of-disturbance (min), number-of-units-per-event (e.g., number of canoes within a

group), visibility-of-disturbance-to-affected-eagle (none/any), position-relative-to-affected-eagle (above/below), and sound-at-affected-eagle (none/any) for each event. Observations, referenced to age class of affected eagle (12 adults and 10 nestlings), began near hatching and ceased at fledging. Nestling response was not recorded until the young became visible at about 5-6 weeks of age. We recorded adult eagle activity as nest attending or perching away from nest.

All human activity data were collected passively. We could not establish definitive cause and effect relationships because we did not under controlled, experimental conditions disturb breeding eagles to the point of failure or reduced productivity. Disturbances were not initiated but only recorded as they occurred. Distances were measured on topographic maps and aerial photographs, or otherwise estimated from available landmarks. Medians were used in summary statistics to represent central tendencies because of skewness in the data caused by a preponderance of nearby, short-duration human activities. For analysis, times were rounded off to the previous whole hour (e.g., 1700-1759 = 1700). Frequencies, descriptive statistics, and chi-square tests of independence (P to thousandths) were calculated with SPSS/PC+ (Norusis 1986). We used notched box and whisker plots (P=0.05; Chambers et al. 1983; STSC 1987) to evaluate variation in distance-to-disturbance among classes of several variables, including response type.

We developed classification and regression tree (CART) models to measure disturbance, estimate response severity, and develop disturbance-specific management considerations (Brieman et al. 1984; California Statistical Software, Inc. 1985; Grubb and King 1991). Only the classification tree aspects of CART were used in our analyses. Classification analysis identifies the most accurate classifiers (predictor or splitting variables) and provides predictive, discriminant models in the form of nonparametric, dichotomous keys (Brieman et al. 1984; Verbyla 1987). The variable that best partitions the data into the purest classes of response (none/any) is incorporated at each step of the model. Each variable is also ranked for its splitting ability by assigning the primary (first) splitting variable a value of 100% and expressing the relative value of secondary variables as a percentage of it. We developed CART models for pooled disturbances (all disturbance groups for all sites) and for each of the five disturbance groups. Cross-validation provided an estimate of classification accuracy for each tree.

Results

Disturbance summary

We recorded 714 events of potentially disturbing human activity for analysis. Aircraft was the most common activity type observed near breeding eagles, followed by aquatic, vehicle, noise, and pedestrian disturbance (Figure 1, Table 1). Vehicles elicited the highest within-group response frequency and aircraft the lowest; aquatic and pedestrian activities were about equal ($P<0.001$). Overall response was highest for aquatic and aircraft activity, because these two activities were the most frequent near breeding eagles in northcentral Michigan (Figure 1). Aquatic disturbance had the shortest median distance to affected eagles, and noise the greatest ($P<0.05$). Aircraft activity, influenced by circling military jets near one nest on the Au Sable River (Table 2), had the longest median duration ($P<0.05$), followed by pedestrian and vehicle traffic ($P>0.05$).

TABLE 2. Comparison of disturbance and response characteristics of breeding Bald Eagles near a military air base with five other breeding areas in northcentral Michigan, 1990.

	Disturbance				No Response		Response	
Group/ Type	Frequency (no. of events)	Median no. per event	Median distance (m)	Median duration (min)	Frequency (%)[a]	Median distance (m)	Frequency (%)[a]	Median distance (m)
Military Site:								
Aircraft	**280**	**2.0**	**800**	**12.0**	**73**	**800**	**27**	**400**
Jets	214	2.0	800	13.0	71	800	29	400
Light Planes	23	1.0	1500	3.0	100	1500	0	–
Helicopters	43	1.0	700	5.0	72	800	28	700
Other Breeding Areas:								
Aircraft	**61**	**1.0**	**800**	**1.0**	**59**	**800**	**41**	**800**
Jets	27	1.0	800	1.0	44	800	56	800
Light Planes	29	1.0	800	1.0	72	800	28	800
Helicopters	5	1.0	400	2.0	60	407	40	400

[a] Response frequency (%) = response sample size divided by number of events x 100%.

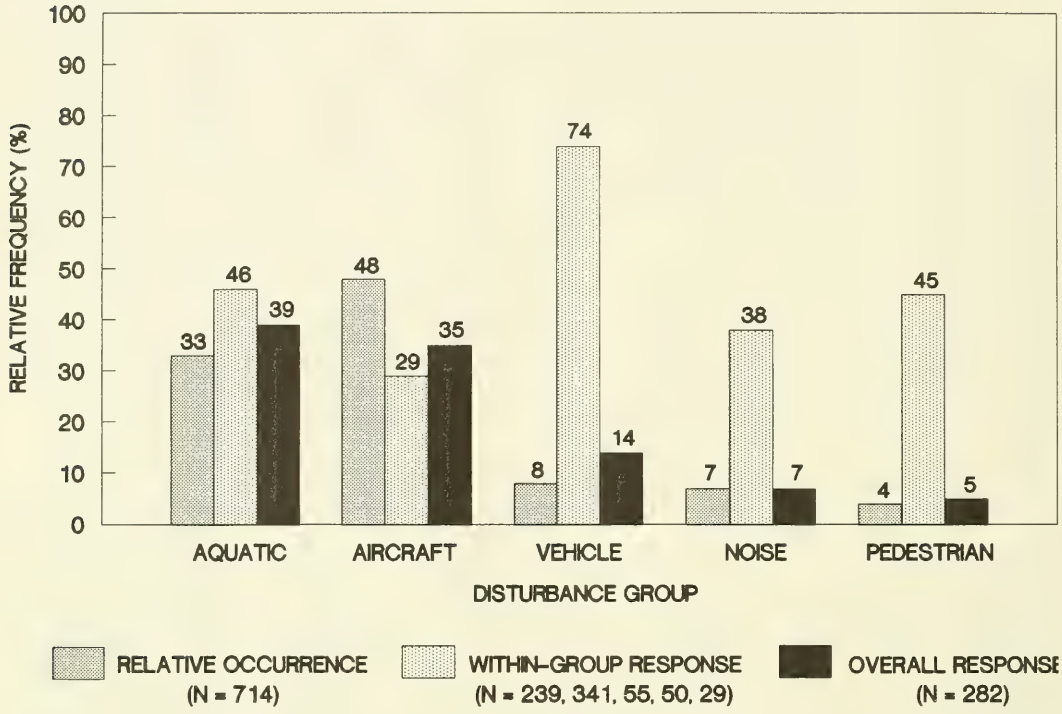


FIGURE 1. Relative frequency of occurrence, within-group response, and overall response for 714 events of, and 282 responses to, five human disturbance groups near breeding Bald Eagles in northcentral Michigan, 1990 (N = 341 aircraft, 239 aquatic, 55 pedestrian, 50 noise, and 29 vehicle).

Among specific disturbance types, artillery, gunshots, canoes, ATVs, and jets typically occurred with multiple units-per-event, whereas all other activities tended to occur singly (Table 1). Anglers, autos, and gunshots elicited the highest frequencies of response ($P<0.001$). Among aircraft, light planes caused the lowest response. Helicopters occurred closest to eagles of any aircraft ($P<0.05$) and tended to have the longest duration in non-military situations ($P>0.05$, Table 2). Jets and helicopters elicited comparable response frequencies ($P = 0.663$), but the median distance for response was 200 m greater for helicopters ($P<0.05$). Median distance-for-response was smallest for anglers and canoes, but there was more than a three-fold difference in response frequency between these pedestrian and aquatic activities ($P = 0.018$). Excluding the separate noise category in Table 1, ground-related disturbance elicited highest response (64%), followed by water (46%) and airborne (29%) activities ($P<0.001$).

Disturbance characteristics

Magnitude of response, as indicated by type and/or frequency, consistently increased as median distance-to-disturbance decreased for all disturbance types, although distance ranges for each type of Bald Eagle response overlapped (Table 1). The median distance for awareness for all disturbance types, as indicated by alert behavior, was 300 m, and for flight, 100 m (Figure 2). Tops of boxes indicate the distance within which 75% of the recorded responses occurred. Non-overlapping notches in the boxes indicate significant differences among median distances for the three levels of response ($P<0.05$). Number, position, and visibility when analyzed independently had little apparent, direct effect on response type or severity. However, when disturbances were audible to eagles, frequency of response appeared to increase (from 22 to 40%, N = 18 and 696, respectively).

Eagle age and activity

We recorded 421 (59%) adult and 293 (41%) nestling responses to human activity. Adults consistently exhibited greater response frequencies than nestlings (45 versus 31%, $P<0.001$), but median distance-to-disturbance for response (300 m) did not differ between age classes ($P>0.05$). Adult and nestling response frequencies were similar for most distur-

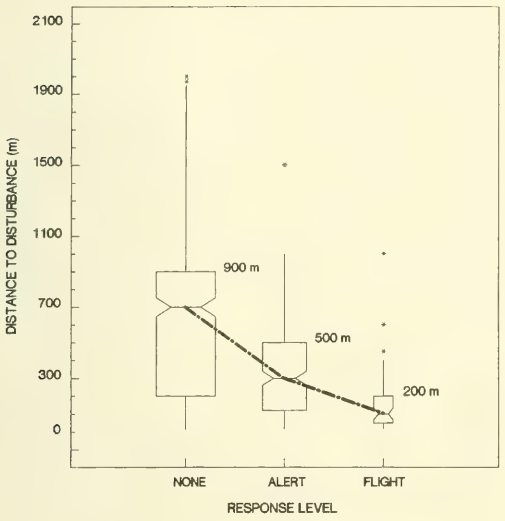


FIGURE 2. Median distance-to-disturbance by response level for 714 events of human activity near breeding Bald Eagles in northcentral Michigan, 1990 (N = 432 none, 235 alert, 47 flight). (Boxes cover middle 50% of data. Whiskers indicate range but do not exceed 1.5 times box length. Box width is proportional to sample size. Center lines are medians, with position indicating skewness. Notches are width of 95% confidence intervals for pairwise comparisons.)

bance types, but adults showed higher response to light planes (20 versus 9%), boats (57 versus 30%), and canoes (33 versus 17%), although only the boat increase was statistically significant (P = 0.281, 0.002, and 0.375, respectively). Adults also exhibited an 80% response to anglers, but anglers were not recorded in view of nestlings. Flight response frequencies for adults by disturbance group were pedestrian 17%, vehicle 11%, aquatic 8%, aircraft 5%, and noise 2% (N = 36, P = 0.022). Overall flight response was 9%. Nest-attending adults responded at a greater median distance-to-disturbance than when perched away from the nest (300 versus 100 m, P<0.05). However, frequency of response remained unchanged (45 and 47%, respectively).

Breeding area variation

Relative frequency and type of disturbance, response frequency, median distance-to-disturbance for response, and weekend activity varied among breeding areas (Table 3). The military site experienced the most human activity (N = 382) but these eagles showed the least response (33%). Aircraft (79%) was the predominant activity at nest sites on the Au Sable River (N = 445), and aquatic activity (69%), on the Manistee (N = 269). Median distance-to-disturbance (700 m) and median distance-for-response (350 m) on the Au Sable were both greater than on the Manistee (200 and 142 m, respectively; P<0.05). The Manistee, however, had a higher response frequency (49 versus 34%, P<0.001).

Timing

May was the peak month for human activity near breeding Bald Eagles in northcentral Michigan in 1990 (Table 4). Median distance-to-disturbance and median response distance tended to decline from March to June, with the largest decrease occurring in June. Response frequency also decreased over the period. Aquatic activity increased (22% April, 35% May, 48% June), whereas other disturbance groups showed little monthly change. In April and June, 75 and 74% of recorded human activity, respectively,

TABLE 3. Individual breeding area variation in disturbance and response characteristics for Bald Eagles in northcentral Michigan, 1990.

	Breeding Areas					
	Au Sable River				Manistee River	
Characteristic	1[a]	2	3	4	5	6
Sample size (N)	382	9	4	50	132	137
Disturbance						
Vehicle (%)	13	0	0	2	4	0
Pedestrian (%)	5	0	75	4	0	4
Aquatic (%)	0	89	0	38	80	77
Noise (%)	9	0	0	4	0	10
Aircraft (%)	73	11	25	52	16	9
Weekend (%)	46	89	50	76	85	70
Median distance (m)	800	50	250	750	100	300
Response						
Frequency (%)	33	44	50	33	48	50
Median distance (m)	350	80	230	800	100	300

[a] Breeding area adjacent to military air base.

TABLE 4. Monthly comparison of disturbance and response characteristics for breeding Bald Eagles in northcentral Michigan, 1990.

	Disturbance				No Response		Response	
Month	Frequency (no. of events)	Median no. per event	Median distance (m)	Median duration (min)	Frequency (%)[a]	Median distance (m)	Frequency (%)[a]	Median distance (m)
March	3	–	–	–	33	–	67	–
April	223	2.0	500	3.0	54	800	46	300
May	326	1.0	450	5.0	62	700	38	300
June	162	1.0	200	1.5	67	350	33	100

[a] Response frequency (%) = response sample size divided by number of events x 100%.

occurred on weekends, but in May, weekend occurrence was 44%.

During this study 60% of observed human activity occurred on weekends (N = 431, versus 283 for weekdays). Weekend activity predominated at four breeding areas and was nearly equal to weekday activity at two others. Median distance-to-disturbance was less on weekends (300 versus 600 m, $P<0.05$). The increase in median distance-for-response from 200 to 300 m on weekends was not significant ($P>0.05$). Weekend response frequency was 44%, and weekday, 32% ($P = 0.001$). Weekend frequencies of occurrence by disturbance group were vehicle 56%, pedestrian 41%, aquatic 80%, noise 62%, and aircraft 48%. Boats, autos, ATVs, and anglers occurred more commonly on weekends, while canoes and hikers were more frequent on weekdays.

Human activity near breeding Bald Eagles was recorded throughout daylight hours. However, most human activity occurred after noon (72%, N = 513), with a midday peak between approximately 1300-1500, and secondary peaks between 0900-1100 and 1600-1900 (Figure 3). Frequency patterns varied

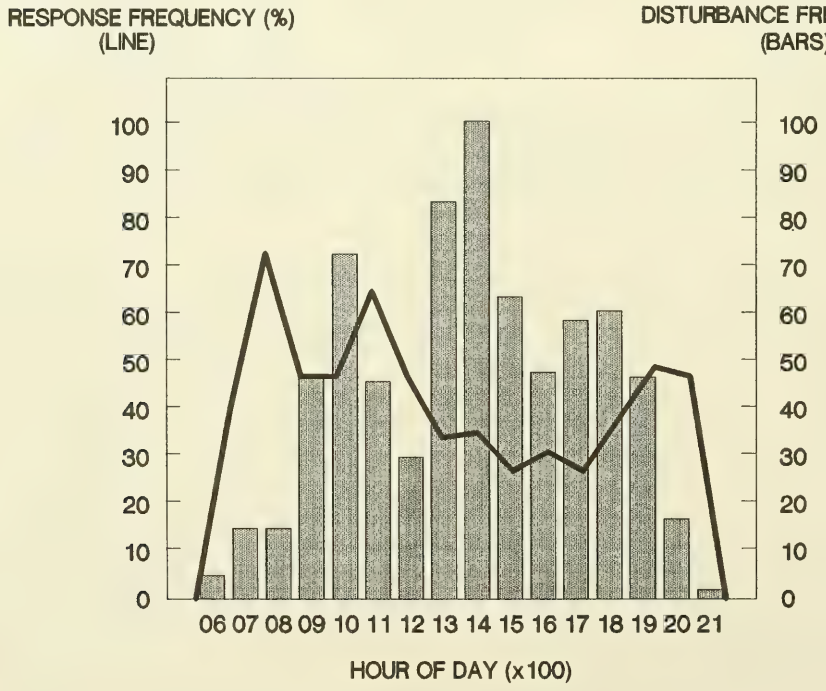


FIGURE 3. Disturbance (N) and response (%) frequency by hour for 714 events of human activity near breeding Bald Eagles in northcentral Michigan, 1990.

among disturbance groups ($P<0.001$), but most pedestrian activity (72%) occurred during the afternoon peak. Response was highest at 0800, followed by lesser peaks at 1100 and 1900 (Figure 3). Response frequency was lowest between 1300-1700, when the occurrence of human activity was greatest. Both median distance-to-disturbance (500 versus 300 m, $P<0.05$) and response frequency (51 versus 35%, $P<0.001$) were higher before 1200. Median distances-for-response were similar before and after noon (300 and 250 m, $P>0.05$).

Classification tree modeling

Distance was the most important classifier, or splitting variable determined by the CART analyses; it occurred at the first or primary split of all models (Figure 4). The relative importance of other parameters for classifying observations (Table 5) varied among sites and disturbance groups, but duration (evident in four of the six models) and number were consistently ranked second and third. The exception was pedestrian activity where sound and visibility were more critical than duration or number. Overall rankings were similar to Grubb and King's (1991) in Arizona. Throughout the CART models, response severity varied inversely with distance and increased with disturbance duration, number-per-event, visibility, and sound. The pooled model shows 55% response when disturbance occurred within 545 m of an eagle versus 17% farther away. Within 545 m, a duration >3.5 min caused 71% response, and <3.5 min, 44%. If sound was associated with the longer disturbance, response was 75%, versus 25% if quiet. Estimated classification accuracy for this model was 0.74.

By disturbance group, vehicles elicited 95% response within 750 m. Short duration (≤ 2.5 min) reduced this frequency to 60%. The primary split for pedestrian disturbance was 185 m. Beyond that distance, quiet activity lowered eagle response. Response frequencies were relatively high on both sides of the 66-m split in the aquatic tree, with shorter durations tending to reduce responsiveness at greater distances. Median distance to disturbance for the 41%-response side of this model was 200 m (n = 198, range 75–1500 m). Noise had the largest primary split of the disturbance groups considered, with 76% response within 850 m and no response beyond. Visibility of the noise source more than halved response within 850 m. Aircraft caused the lowest left-side, response frequency of the five disturbance groups. Short duration flights (≤ 2.5 min) within the 550-m primary splitting distance greatly reduced response. Accuracy estimates for these models were vehicle 0.96, pedestrian 0.69, aquatic 0.57, noise 0.88, and aircraft 0.85.

Discussion

General summary

Within-group response provides a measure of relative impact among specific disturbance groups, whereas overall response combines occurrence (frequency of a disturbance group) with the within-group response to give an assessment of current disturbance levels. Vehicles caused the highest within-group response, yet aquatic and aircraft activities appeared to be having a greater effect on breeding eagles because of more frequent interactions. The question of which is more detrimental, few high-response activities or frequent low-response ones, requires further research into the relationship of response frequencies to behavior modification and ultimately to productivity. Grubb and King (1991)

TABLE 5. Relative importance[a] of independent (splitting) variables in CART analyses for pooled and five groups of human disturbance recorded near breeding Bald Eagles in northcentral Michigan, 1990.

	Disturbance						Overall Ranking	
Variable	Pooled	Vehicle	Pedestrian	Aquatic	Noise	Aircraft	MI	AZ[b]
Distance	100	100	100	100	100	100	1	1
Duration	61	42	34	99	35	89	2	2
Number	53	0	37	42	33	49	3	4
Visibility	16	0	41	2	29	5	4	3
Sound	11	0	67	7	0	0	5	6
Position	21	1	0	0	0	3	6	5

[a] Standardized so primary splitting variable = 100% and secondary variables are expressed as a percentage of it.
[b] From 13 breeding areas, 1983-1985 (Grubb and King 1991).

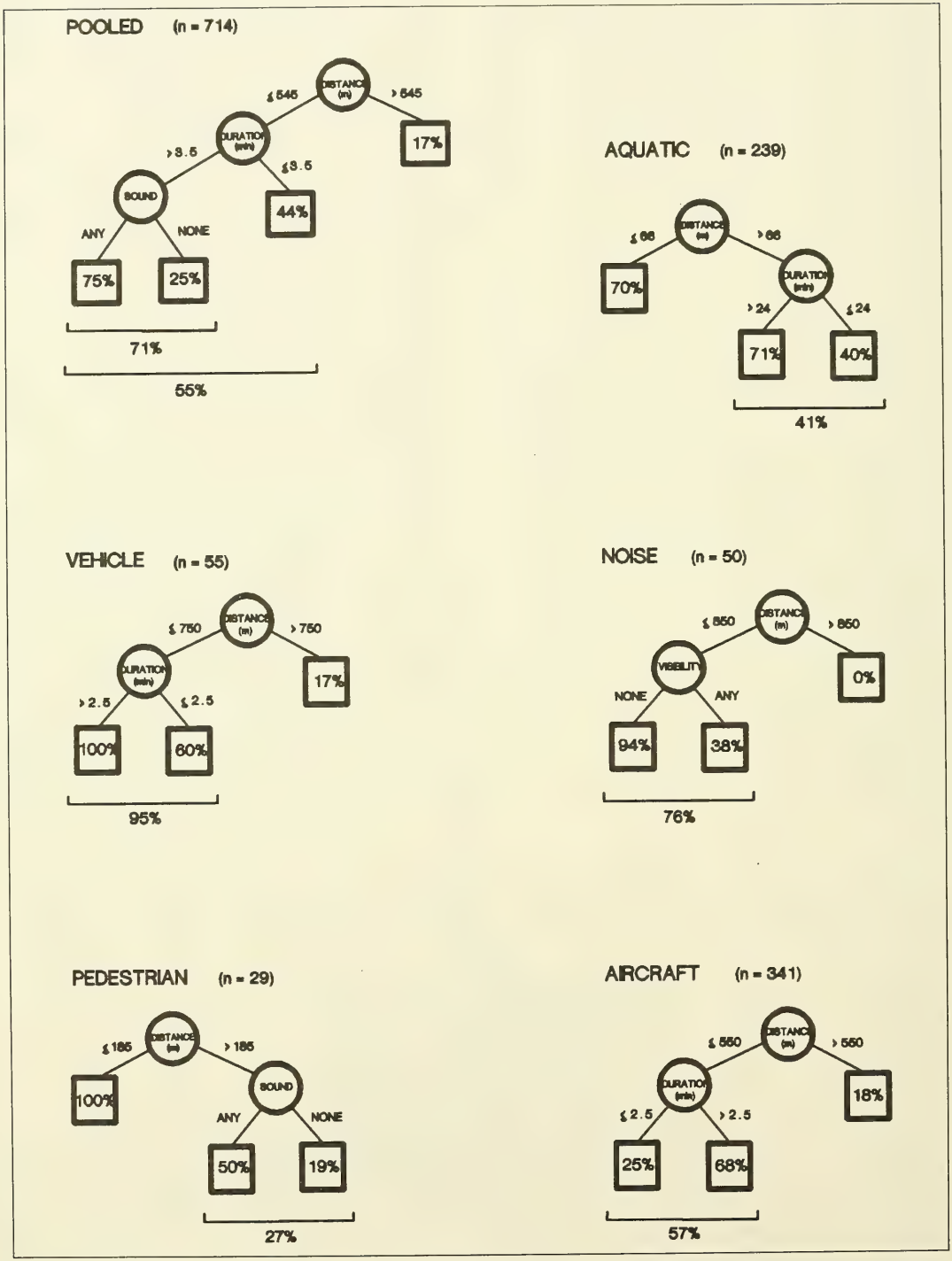


FIGURE 4. Classification tree (CART) models, with associated eagle response frequencies, for pooled and five separate human disturbance groups, recorded near breeding Bald Eagles in northcentral Michigan, 1990.

recommended at least nine parameters, relating to the nature and timing of the disturbance and the status of the affected eagle, for consideration on a case-by-case basis in evaluating relative effects of human activity on breeding eagles.

In the current analysis, an increase in distance-to-disturbance for response generally implied greater sensitivity, or intolerance, by eagles because they reacted to the activity farther away (e.g., ATVs elicited the same response as autos but at 2.5 times the distance). However, in some cases greater distances for response may simply reflect distant occurrence (e.g., light planes elicited the fewest responses among aircraft, yet at the greatest median distance). That ground activities showed the highest response, followed by water and air, is consistent with findings in Minnesota (Fraser et al. 1985) and in Arizona (Grubb and King 1991). Similar disturbance and response characteristics for Michigan and Arizona (Table 1) are evidence for consistency in the nature of disturbance around breeding Bald Eagles, and substantiate observed levels of response within each geographic area.

Although the frequencies of response to pedestrian (45%) and aquatic (46%) activities were similar, median distances for response indicated that aquatic activity can occur closer to eagles with no increase in effect (100 versus 185 m). Canoes, presumably because of their usually quiet unobtrusive occurrence, elicited half the response of power boats at half the distance (24% at 50 m versus 48% at 100 m). The wide disparity in response frequencies for noise types (0% artillery, 76% gunshots) suggests that eagles near the military base tolerate the sound of distant artillery. The response to gunshots is more likely representative of the effect of abrupt loud noise, or perhaps associating previously witnessed mortalities. In Arizona, eagle responses to gunshots and sonic booms were 52 and 63%, respectively (Grubb and King 1991).

Median number-per-event, median durations, and response frequencies for aircraft at other breeding areas (Table 2) better reflect the normal, non-military situation. A larger sample would likely show helicopters cause greater response. Arizona response frequencies for jets, light planes, and helicopters were 30, 27, and 47%, respectively (Grubb and King 1991). The lower aircraft response frequency and much smaller response distance for the military site in comparison with the other areas (400 versus 800 m), especially as both groups had the same median distance of occurrence (800 m), also indicates a habituation to military air activity.

Disturbance characteristics

Generally, if the median distance-to-disturbance for occurrence of any disturbance group or type (Table 1, column 4) was much less than the median distance-for-no-response (column 7), response frequency was high (e.g., all vehicle categories). When these distances were approximately equal, response frequency was typically lower (e.g., all aircraft categories). Although the median distance-to-disturbance for initial (alert) response was 300 m (Figure 2), a better estimate of threshold for response is 500 m, the distance within which 75% of the alert responses occurred. Similarly, 200 m is a more appropriate estimate of a threshold for flight. In Oregon, McGarigal (1988) recorded an alert distance for boating activity of 400–500 m and flight distance of 150–220 m. In Minnesota, Fraser et al. (1985) have determined 500 m to be a minimum distance to avoid disturbance near breeding Bald Eagles.

Age and activity

Nestlings were not as responsive to human activities as adults, but when they responded, they did so at the same median distance-to-disturbance as the adults. This may suggest learned awareness and instinctive reaction. Free-flying immatures have also been found to respond by flying at distances similar to adults (Buehler et al. 1991). Reduced visibility out of the nests, as compared to adults' high perches, may partially account for nestlings' reduced responsiveness to light planes, boats, and canoes. The greater distance-to-disturbance for response indicates adults were less tolerant of disturbance when attending young at the nests than when perched elsewhere.

Breeding area variation

Variation in response among individual pairs of eagles and among disturbance groups for the six breeding areas demonstrates the need for disturbance (human activity), site (habitat), and pair (behavior) specificity in Bald Eagle research and management (Mathisen et al. 1977; Fraser 1985; Grubb and King 1991). The higher response frequency on the Manistee River appears to be associated with the closer proximity of human activity and most of that activity being aquatic, which generally elicits higher response than airborne activity. These trends all remained intact when the military site was removed from the Au Sable data set.

Timing

Since all six study pairs were at approximately the same stage in the nesting cycle, the seasonal decline in frequency and median distance-to-disturbance for response is likely related to a reduction in nest attentiveness that typically occurs as nesting progresses (Newton 1979). Increased visual and audio buffering by developing canopy foliage during the breeding season may also be a factor. Buehler et al. (1991) postulated seasonal variation in responsiveness of eagles on Chesapeake Bay resulted from decreased sensitivity to increased human interactions. In Michigan, the May peak in human activity was likely influenced by a combination of good weather and a spring time increase in recreation activity with the

opening of fishing seasons, Memorial Day, etc. The high response frequency shown for March may not be unrealistic even though the sample was small (2 days versus 9–10 each for the other months). Eagles and other birds of prey are most vulnerable to, and most highly impacted by, disturbance early in the breeding season (Fyfe and Olendorff 1976; U.S. Fish & Wildlife Service 1981). Increased eagle response on weekends was apparently caused by a higher frequency of human activity and closer proximity of that activity. The morning and smaller evening peaks of eagle responsiveness were likely related to nest-attending and foraging activity. Similarly, low eagle response in the afternoon period of highest human activity may relate less to conditioning than to eagles' typical diurnal pattern of perching quietly, sunning or loafing for hours during this period.

Classification Tree Modeling

CART analysis provides insight into critical distances associated with different response frequencies, and into the synergistic interaction among disturbance characteristics. Although CART readily accommodates small data sets such as encountered in these analyses, reliability and general applicability of such models must be viewed with caution. Inclusion of a variable in the CART models reflects its ability to separate responses for the subset of data occurring at that node, not necessarily its relative importance within a disturbance group. Splits solely on distance indicate any type of disturbance within the group, regardless of other characteristics (number, sound, duration, etc.), evoked response at the frequency shown.

The implied acceptance of pedestrian activity closer than vehicles both in the CART models and Table 1 is more likely an artifact of pedestrian activity occurring closer rather than the result of a greater tolerance to pedestrians, which would not be expected (Grubb and King 1991). The small splitting distance for aquatic activity also reflects proximity, and perhaps in this case, greater tolerance. However, the relatively high response frequencies on the right or low-response side of this model limit its usefulness, beyond implying a benefit to shorter duration activity. This was also the least accurate of the models constructed. The mitigating influence of visibility in the noise model is best explained by a reduced startle effect when the source of noise is seen (Fyfe and Olendorff 1976).

Differences between primary splitting distance in the CART models and the median distance-for-response for each disturbance (Table 1, column 9) are explained by CART's consideration of the range rather than frequency of distances. In most cases, CART splits occurred at distances greater than the median response distance. Deviations in either direction indicated a wide range of distances-to-disturbance eliciting response. Comparison of overall rankings with Arizona findings (Grubb and King 1991) substantiated the primary and secondary importance of distance and duration, while suggesting number and visibility were next and comparable in general effect, followed similarly by sound and position. Rankings of primary and secondary splitting variables provided by CART can be used to compare and contrast the relative importance of different characteristics within specific disturbance groups or at individual nest sites.

Management Implications

Although CART facilitates improved specificity for site, disturbance, and temporal analyses, consistencies in the Michigan and Arizona results indicate broadly applicable management criteria, while dissimilarities evidence those aspects of disturbance requiring local analysis. Median distances to disturbance for different types or levels of response were similar for both studies and consistent with results from other areas as referenced above. Thus, without local data to the contrary, management of human activities for the protection of breeding Bald Eagles should begin with a no-activity primary zone (Mathisen et al. 1977) at 500–600 m from nest sites, followed by a secondary zone at 1000–1200 m. Flight is typically induced by disturbance at 200–300 m; effective breeding area management should avoid this response.

The Michigan and Arizona studies confirm the traditional importance of distance as the primary characteristic of human disturbance influencing Bald Eagle response. Classification analyses indicated disturbance duration is the second most important criterion for management. Number and visibility are tertiary considerations, followed by sound and position. These rankings are generally applicable; however, the relative importance of these characteristics can vary among populations and disturbances. Therefore, local verification is recommended. Frequency of disturbance types or groups and associated response rates must be determined locally. With sufficient local data, management can be effectively tailored to specific situations, especially since eagle responsiveness indicates potential for impact. Unfortunately, current analyses cannot be directly related to productivity because of the small number of breeding pairs sampled, the narrow range in productivity measures (1-3 eggs or young), too few years of data, and the inappropriateness of controlled experimentation.

Acknowledgments

A. J. Bath and J. A. Johnston provided invaluable field and data management support. We thank S. A. Hogle, E. Malleck, J. T. Painter, B. Richardson, T. Ridley, B. Rogers, J. Rogers, P. Stefanek, S. Sutton, S. Thompson, T. J. Warren, and D. Weeks, as well

as volunteers from EARTHWATCH, for assistance in data collection. K. R. Ennis, C. Schumacher, G. Huntington, and A. Sikkegna provided logistical and field support. J. Janssen helped develop the CART models. J. E. Mathisen, S. K. Skagen, and T. F. Weise provided helpful reviews of an earlier draft. We also appreciate the additional reviews of G. R. Bortolotti and two anonymous journal referees. This study was cooperatively funded by Consumers Power Company, Michigan State University, USDA Forest Service, and EARTHWATCH.

Literature Cited

Brieman, L., J. H. Friedman, R. A. Olshen, and **C. J. Stone.** 1984. Classification and regression trees. Wadsworth & Brooks, Monterey, California. 358 pages.

Buehler, D. A., T. J. Mersmann, J. D. Fraser, and **J. K. D. Seegar.** 1991. Effects of human activity on Bald Eagle distribution on the northern Chesapeake Bay. Journal of Wildlife Management 55: 282–290.

California Statistical Software, Inc. 1985. CART (TM). California Statistical Software, Inc., LaFayette, California. [Unnumbered]

Chambers, J. M., W. S. Cleveland, B. Kleiner, and **P. A. Tukey.** 1983. Graphical methods for data analysis. Wadsworth International Group, Belmont, California. 395 pages.

Forbis, L. A., T. G. Grubb, and **W. E. Zeedyk.** 1985. A volunteer bald eagle nest watch program on Arizona national forests. Pages 246-254 *in* Proceedings of Bald Eagle Days, 1983. *Edited by* J. M. Gerrard and T. N. Ingram. The Eagle Foundation, Apple River, Illinois.

Fraser, J. D. 1985. The impact of human disturbance on Bald Eagle populations – a review. Pages 68-84 *in* Proceedings of Bald Eagle Days, 1983. *Edited by* J. M. Gerrard and T. N. Ingram. The Eagle Foundation, Apple River, Illinois.

Fraser, J. D., L. D. Frenzel, and **J. E. Mathisen.** 1985. The impact of human activities on breeding Bald Eagles in north-central Minnesota. Journal of Wildlife Management 49: 585–592.

Fyfe, R. W., and **R. R. Olendorff.** 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Canadian Wildlife Service Occasional Paper Number 23. 17 pages.

Grier, J. W., J. B. Elder, F. J. Gramlich, N. F. Green, J. V. Kussman, J. E. Mathisen, and **J. P. Mattsson.** 1983. Northern states Bald Eagle recovery plan. U. S. Fish & Wildlife Service, Washington, D.C.

Grubb, T. G., and **R. M. King.** 1991. Assessing human disturbance of breeding Bald Eagles with classification tree models. Journal of Wildlife Management 55: 501–512.

Mathisen, J. E. 1968. Effects of human disturbance on nesting Bald Eagles. Journal of Wildlife Management 32: 1–6.

Mathisen, J. E., D. J. Sorenson, L. D. Frenzel, and **T. C. Dunstan.** 1977. A management strategy for Bald Eagles. Transactions 42nd North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington, D.C. 42: 86–92.

McGarigal, K. 1988. Human-eagle interactions on the Lower Columbia River. Master of Science thesis. Oregon State University, Corvallis. 115 pages.

Newton, I. 1979. Population ecology of raptors. Buteo Books, Vermillion, South Dakota. 397 pages.

Norusis, M. J. 1986. SPSS/PC+. SPSS, Inc., Chicago, Illinois. [Unnumbered].

STSC. 1987. Statgraphics, statistical graphics system. Statistical Graphics Corporation, Rockville, Maryland. [Unnumbered],

U. S. Fish & Wildlife Service. 1981. Bald Eagle management guidelines Oregon-Washington. Portland Area Office, Oregon. 10 pages.

Verbyla, D. L. 1987. Classification trees: a new discrimination tool. Canadian Journal of Forest Research 17: 1150–1152.

Received 17 February 1992
Accepted 28 April 1993

The Origin, Physico-chemistry and Biotics of Sodium Chloride Dominated Saline Waters on the Western Shore of Lake Winnipegosis, Manitoba

W.B. McKillop[1], R.T. Patterson[2], L.D. Delorme[3], and T. Nogrady[4]

[1]Manitoba Museum of Man and Nature, 190 Rupert Avenue, Winnipeg, Manitoba R3B ON2
[2]Ottawa-Carleton Geoscience Center and Department of Earth Sciences, Carleton University, Ottawa, Ontario K1S 5B6.
[3]Lakes Research Branch, National Water Research Institutue, Canada Centre for Inland Waters, Burlington, Ontario L7R 4A6 and Quaternary Sciences Institute, University of Waterloo, Waterloo, Ontario N2L 3G1
[4]Deptartment of Biology, Queen's University, Kingston, Ontario K7L 3N6

McKillop, W. B., R. T. Patterson, L. D. Delorme, and T. Nogrady. 1992. The origin, physico-chemistry and biotics of sodium chloride dominated saline waters on the western shore of Lake Winnipegosis, Manitoba. Canadian Field-Naturalist 106(4): 454–473.

Twenty-three sodium chloride dominated saline sites clustered along the western shore of Lake Winnipegosis were studied over a three year period. Sites were classified into four habitat categories based in part on salinity, which frequently exceeded that of oceanic environments. The source of the saline waters together with associated physico-chemical factors and unique biological communities are described. In addition to an unique flora, members of five animal phyla Chordata, Protozoa, Rotifera, Arthropoda, and Mollusca, were present. Of these only the Mollusca lacked marine representation. Transport of the marine species by birds from coastal areas is suggested.

Vingt-trois sites aquatiques salins dominés principalement par le chlorure de sodium et regroupés le long du secteur ouest du lac Winnipegosis ont été étudiés sur une période de plus de trois ans. Ces sites ont été regroupés en quatre catégories d'habitats selon leur salinité, laquelle dépasse souvent celle des océans. Les causes de cette salinité, les facteurs physico-chimiques de même que les communautés biologiques uniques sont décrites. En plus de la flore unique, les phylums de Chordés, Protozoaires, Rotifères, Arthropodes et Mollusques sont représentés. De ces phylums, seul les Mollusques n'ont pas de représentation marine. Il est suggéré que les oiseaux des régions côtières ont probablement transporté les expèces marines.

Key Words: Sodium chloride dominated, inland saline waters, origin, water quality, plants, invertebrates, birds, distribution, immigration, speciation, Manitoba.

Henry Hind (1971) in his historical narrative of 1858 commented on the many salt springs bordering Lake Winnipegosis. Tyrrell (1892) analysed the spring water and suggested that the salinity originated from dissolution of salt found in rocks of late Silurian or early Devonian age, and that the salt formed a considerable portion of these dolomitic beds. Cole (1915) provided two additional hypotheses: the first that the brines are residual sea water; and the second, that meteoric waters simply leached a salt bed lying immediately to the west.

More recently Hitchon (1969), Hitchon et al. (1969), Hitchon et al. (1971), McCabe and Barchyn (1982) and Simpson et al. (1987) studied the regional groundwater flow systems and suggested that the western shore of Lake Winnipegosis formed a discharge area for intermediate and regional scale systems originating in the Manitoba Uplands to the west of the lake and, more regionally, within the upland areas of the Western Canada Sedimentary Basin and the Northern Great Plains Region of the United States. Cameron (1949), van Everdingen (1971) and Stephenson (1973) examined the springs' geochemistry. Wadien (1984) concluded that the low Br/Cl ratios indicated that the salinity resulted from halite dissolution of the Devonian Prairie Evaporite formation by circulating meteoric waters but suggested that stable isotope determinations be made.

Study of raised Lake Agassiz beaches (Nielsen et al. 1987) demonstrated the presence of two brackish-water micro-invertebrate fossils, the ostracode *Cytheromorpha fuscata* (Brady) and the foraminiferan *Cribroelphidium gunteri* (Cole). The former had been reported previously from the area (Delorme 1973, 1974a, 1974b, 1977; Neale and Delorme 1985). Later in 1987, D.B. Scott (Dalhousie University) found the foraminiferan *Trochammina (Jadammina) macrescens* Brady alive in a nearby salt marsh from samples provided by Neilsen and McKillop. Both foraminiferal species are extant today in coastal marine waters (Nielsen et al. 1987; Scott and Martini 1982).

The objective of the study was to describe in detail the chemical composition of the sodium chloride dominated waters and to determine whether these or other ecological parameters govern the distribution of the invertebrates in these little known and unique habitats.

Methods and Materials

The Study Sites (Figure 1, 2a-d and Tables 1, 2 and 3)

Biological and water samples were taken six times during 1988 and 1989 at twenty three saline sites identified along the western shore of Lake Winnipegosis. These sites were heuristically divided into four ecological categories based mainly on vegetation, rate of discharge and filterable residue.

Subsaline or fresh waters (Sites 3, 9, 13, 14 and 19).

The majority of these sites were fed by streams or runoff containing low concentrations of salt water (Figure 2a). Where waters pooled a pan was evident; otherwise these sites consisted simply of the stream bottom. The flow was slow and during the summer most sites dried up.

Hyposaline salt marshes (Sites 1, 2, 5, 6, 11, 12 and 17)

In these sites water chemistry varied greatly depending on the proportion of salt water to surface runoff. Although similar to fresh water marshes these sites had a barren pan (Figure 2b). The vegetation was distributed in concentric zones at most sites.

Mesosaline salt springs and salt seeps (Sites 4, 7, 8, 10, 15 and 21)

The flow rate at the salt seeps was minimal: minute seepages serve as the salt water source. Only a few millimetres of water covered the pan which made sampling difficult especially in summer when some sites almost dried up. Crystal encrustations of precipitates were often seen near the discharge sites.

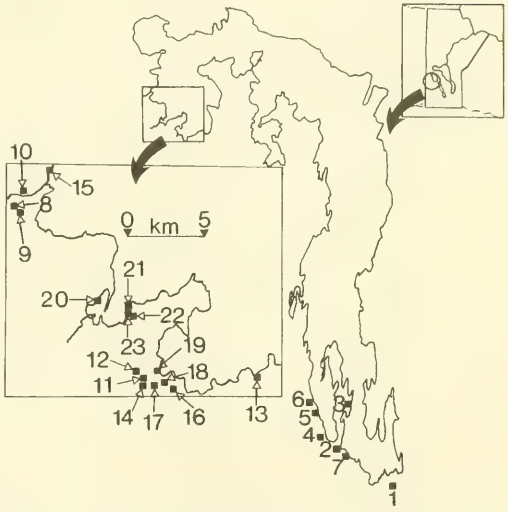


Figure 1. Map of area showing location of study sites on western shore of Lake Winnipegosis, Manitoba. See Table 3 for site descriptions.

Figure 2. Sites typical of the four ecological categories clockwise from the upper left corner:
2a. (upper left) Subsaline fresh water Site 3
2b. (upper right) Hyposaline salt marsh Site 2
2c. (lower right) Mesosaline salt seep Site 8
2d. (lower left) Hypersaline Dawson Bay salt spring Site 16

TABLE 1. Soil salinity and plant distribution in the various habitat categories.

Habitat	Zone	Mean Soil Salinity	Plant Species D E F G H I J K L M N O P Q R S T U V W X Y Z 1 2 3 4 5 6 7 8 9
Subsaline Fresh Waters			
	Pan	12520	NONE
	Zone 2	9160	D F K L M T 5 6 9
	Zone 3	6520	G H J K L N P T V X Y 1 2 4 7
	Zone 4	4400	D F H K N R S T U V X 1 2 6 7 8
Hyposaline Salt Marshes			
	Pan	24670	NONE
	Zone 2	22800	D E F G H K M R S T 2
	Zone 3	15150	D F G H K L N O P Q T 3
	Zone 4	9690	F G H J K L R S
	Zone 5	2720	K L S W Y 1 2 6
Mesosaline Salt Springs and Salt Seeps			
	Pan	33580	NONE
	Zone 2	23610	D E F G I K L Q
	Zone 3	20780	D E F G H I K L M N P R S T
	Zone 4	11960	E G H J K L M O P S T Y Z
	Zone 5	5000	H K L M T V W Y Z 1
Dawson Bay Hypersaline Salt Springs			
	Pan	45020	NONE
	Zone 2	28010	D E F G H K L N R T X Y
	Zone 3	16850	E F G H I K L N P Q R S T U W Y
	Zone 4	11770	G H I K L S T Z
	Zone 5	8540	G H K T Z

Plant species

D	*Salicornia rubra* Nels.	T	*Sonchus arvensis* L.
E	*Spergularia marina* Griseb.	U	*Achillea millefolium* L.
F	*Suaeda depressa* S. Wats.	V	*Lycopus uniflorus* Michx.
G	*Puccinellia nuttalliana* Hitchc.	W	*Hierochloe odorata* Beauv.
H	*Hordeum jubatum* L.	X	*Potentilla anserina* L.
I	*Distichlis stricta* Rydb.	Y	*Calamagrostis inexpansa* Gray
J	*Grindelia squarrosa* Dunal	Z	*Ambrosia psilostachya* D.C.
K	*Triglochin maritima* L.	1	*Phragmites australis* Trin.
L	*Atriplex patula* L.	2	*Helianthus maximilianii* Schrad.
M	*Plantago maritima* L.	3	*Carex lanuginosa* Michx.
N	*Glaux maritima* L.	4	*Solidago* sp.
O	*Artemesia* sp.	5	*Stellaria longifolia* Muhl.
P	*Aster pauciflorus* Nutt.	6	*Typha latifolia* L.
Q	*Spartina gracilis* Trin.	7	*Juncus balticus* Willd.
R	*Aster ericoides pansus* Boivin	8	*Ranunculus cymbalaria* Pursh
S	*Agropyron trachycaulum* Malte	9	*Scirpus paludosus* Nels.

The red sinter bed evident at most sites (Figure 2c) was frequently interspersed with soft mud, making these areas muddy in nature.

Both salt spring sites (4 and 15) appeared to have formed recently. Lacking the red sinter base of the salt seeps and hypersaline springs, pools formed in the soft mud. The flow was moderate and continual. Gas bubbles were frequently seen rising from the cauldrons.

Hypersaline Dawson Bay salt springs (Sites 16, 18, 20, 22 and 23)

As Tyrrell (1892) and Wadien (1984) have indicated, these sites sit on a pan of barren, glacially derived, iron stained, surficial material, frequently surrounded by a fringe of the red salt plant *Salicornia* sp. The pan size varied, in part relative to salt water discharge, ranging from a few square metres to more than 0.3 km^2 (Figure 2d). Around the springs, mounds of the red limonite-stained gravelly sinter often rise to a metre in height. Central to these the springs form a basin or cauldron varying in depth from a few centimetres to more than a metre and up to two metres in diameter. A clear brine fills the cauldrons and flows continuously over the sides to arid pans. Gas bubbles were frequently seen rising

within the cauldrons. Up to five concentric vegetative communities ring the pan.

Sampling

Water Samples

At each site water samples were taken on at least four occasions. These were transported on ice to the laboratory and analysed for the parameters listed in Tables 2 and 4 using methods outlined in the Analytical Methods Manual of the Manitoba Technical Services Laboratory (Anonymous 1980). pH, water and air temperatures were measured in the field.

Selected samples were analysed for stable isotopes of oxygen and hydrogen at the Environmental Isotope Laboratory, University of Waterloo.

Both free and dissolved gas samples were taken from three spring sites. At hummocky sites 10 and 15 samples of trapped water were taken from beneath the surface vegetative mat. These were analysed by Atomic Energy of Canada Ltd., Pinawa.

Bromide was analysed by the Manitoba Research Council, Winnipeg.

Biological Samples

Benthic sediment samples were taken using the methods of Scott and Medioli (1980). Basically, a plexiglass tube with a sectional area of approximately 10 cm^2 was used as a coring device. Planktonic samples were taken with a fine mesh (opening 53.3 μm) nylon handnet while hand picking or a standard handnet (mesh opening of 200 μm) was used for the macro-invertebrates. Samples were then placed in glass jars and a buffered 10% formalin solution added.

Results

Habitat (Table 1, 2 and 3)

At most sites the vegetation was arranged in concentric zones about the pan. While only four zones were recognized around the subsaline fresh water sites, each of the other categories had five zones. Table 1 shows the mean soil salinity and the plant species within each vegetation zone for the four habitat categories. Noteworthy is the increase in species diversity according to vegetation zone within habitat categories, not according to absolute salinity. The loss of fresh water species nearer the pan is offset by an even more significant increase in the more salt tolerant species with maximum diversity reached midway, usually in zone 3.

Here, and in a detailed study of salt flat vegetation 50 km to the north, Jones (1991) found that the least salt tolerant plants were found furthest from the pan while halophytes near the pan are apparently unable to compete in the less saline environments and hence are restricted to these saline sites.

Water Chemistry

Charge Balance Error

Charge balance error was calculated for each water analysis to assess the accuracy of the results. Fully one third (21) of the samples had error of 5% or more and were rejected (Barica, 1975). Throughout the study, samples were collected from Lake Winnipegosis near Site 20 but the charge balance criterion was never achieved. Hence the water quality data from this site were dropped although the biological information is referenced herein.

Ion Sequence and Brine Classification

Using the brine classification system of Eugster and Hardie in Lerman (1978), the waters were designated as either Na or Na-(Ca). Without exception the cation sequences were dominated by sodium followed by calcium, magnesium and potassium. Sodium was an order of magnitude greater than calcium, while magnesium and potassium concentration showed no obvious relationship. Chloride was the dominant anion and was followed by sulphate at all but freshwater sites 9, 13 and 19 where bicarbonate exceeded sulphate. Thus the anion classification was Cl-(SO_4) with Cl-(SO_4)-(HCO_3) for sites 9 and 19 and Cl-(HCO_3) for Site 13.

Salinity and Filterable Residue (Table 2)

Salinity was calculated using the Knudson equation:

$$\text{salinity } ‰ = 1.805 \text{ (chlorinity } ‰) + 0.03$$

Although salinity in the current study is derived from NaCl and not from the more frequently studied $NaSO_4$, the waters are not strictly marine in origin. Hence, we consider filterable residue (total dissolved solids) a more accurate means to gauge and categorize the various waters. A linear (r=0.998) correlation resulted between filterable residue and salinity.

pH (Table 4)

The pH range was much lower than that associated with sulphate dominated saline waters. The mean pH dropped from 8.0 in fresh waters, 7.8 in salt marshes, 7.6 in seeps and springs to 7.2 in the hypersaline salt springs. The mean pH of the cauldron spring sites 4, 15, 16, 20 and 23 was only 6.9 but downstream from the site it became 'alkaline' rapidly. Comparing Site 16 with downstream Site 18 the pH rises from 6.9 to 8.2 while at Site 22 and downstream Site 23 the pH rises from 6.8 to 7.6. At Site 4 the pH in the cauldron was 6.95 whereas 2 m downstream it was 7.9. This was probably related to the loss of carbon dioxide on exposure to the atmosphere, resulting in the observed rapid rise in pH.

Fluoride (Table 4)

Concentrations of fluoride in waters from the salt marshes, seeps and springs were an order of magnitude greater than from fresh waters. The mean concentration for seeps and springs was 1.20 mg/l whereas for the fresh water category it was 0.15 mg/l.

Colour (Table 4)

A gradation in colour was noted from the relative-

ly pristine waters of seeps and springs where colour was usually less than 5 units to fresh water sites where values greater than 50 were encountered.

Ammonia nitrogen (NH_3-N) (Table 4)

The ammonia nitrogen concentration increased from fresh waters to the hypersaline salt springs. Mean measurements were 0.058, 0.196, 1.65 and 3.7 mg/l NH^3-N.

Nitrate and Nitrite nitrogen (NO_3-N + NO_2-N) (Table 4)

Salt marshes generally had the lowest concentrations of nitrate plus nitrite nitrogen. The hypersaline salt springs were also low. At Sites 18 and 23, downstream from hypersaline springs 16 and 22, the nitrate and nitrite nitrogen levels had increased while the ammonia nitrogen was lower resulting from ammonia being oxidized to nitrite and nitrate or escaping as a gas.

Stable Isotopes (Table 4)

Samples from ten sites were analysed for the stable isotopes of oxygen and hydrogen (deuterium). Results are expressed in the usual ∫ notation where

$$\int^{18}O = \frac{\left(^{18}O/^{16}O\right)\text{ sample} - \left(^{18}O/^{16}O\right)\text{ smow}^*}{\left(^{18}O/^{16}O\right)\text{ smow}} \times 10^3$$

and

$$\int D = \frac{\text{(D/H) sample - (D/H) smow}^*}{\text{D/H smow}} \times 10^3$$

*smow refers to Standard Mean Ocean Water

A plot of the ∫D vs $\int^{18}O$ shows that the results lie close to the local meteoric water line defined by Day (1977). This indicates that these saline waters are meteoric in origin and have not been subject to significant evaporation or isotopic exchange. However, they are much "lighter" in isotopic composition than typical modern Manitoba groundwater, ranging in $\int^{18}O$ values from -18‰ to -20‰ as compared to the modern groundwater range of -13‰ to -16‰. Betcher (1991 personal communication) indicates that they are also lighter than the deep sedimentary basin waters with similar TDS. This indicates that the spring waters contain a significant component recharged under much colder climatic conditions

TABLE 2. Water categories, site location, filterable residue and salinity.

Water Categories	Sites	Latitude North	Longitude West	Mean Filterable Residue TDS‰	Mean Salinity Sal‰
Subsaline Fresh Waters					
	19	52° 45' 18"	100° 52' 58"	2.5	1.6
	9	52° 52' 08"	101° 03' 26"	3.3	4.0
	13	52° 44' 45"	100° 44' 55"	4.3	7.0
	14	52° 45' 13"	100° 53' 06"	7.0	6.5
	3	51° 50' 30"	99° 54' 55"	7.5	6.2
Hyposaline Salt Marshes					
	5	51° 47' 43"	100° 06' 00"	9.1	8.3
	11	52° 45' 14"	100° 53' 05"	11.0	10.6
	1	51° 33' 50"	99° 41' 10"	16.8	13.0
	2	51° 40' 37"	99° 57' 00"	19.6	17.5
	6	51° 50' 09"	100° 07' 10"	20.4	18.1
	17	52° 45' 10"	100° 53' 00"	31.1	30.8
	12	52° 45' 16"	100° 53' 08"	31.8	28.6
Mesosaline Salt Springs and Salt Seeps					
	15	52° 54' 10"	101° 01' 15"	34.3	31.7
	4	51° 43' 20"	100° 05' 00"	35.0	31.6
	7	51° 40' 10"	99° 56' 50"	49.1	41.7
	21	52° 48' 07"	100° 54' 50"	50.8	51.1
	8	52° 52' 10"	101° 03' 28"	55.6	51.3
	10	52° 53' 10"	101° 02' 30"	56.6	54.2
Hypersaline Dawson Bay Salt Springs					
	23	52° 47' 57"	100° 54' 49"	60.8	60.6
	16	52° 45' 10"	100° 52' 50"	61.6	60.5
	18	52° 45' 13"	100° 52' 55"	61.7	60.7
	20	52° 48' 10"	100° 57' 20"	63.2	61.0
	22	52° 47' 57"	100° 54' 47"	65.2	60.6

Table 3. Description of sites.

Site 1. Salt marsh. The flow rate from a tiny spring was less than 4 l/hr. The site froze in winter.
Site 2. Salt marsh. On the shore of Lake Winnipegosis the marsh was frequently inundated with fresh water. Small springs flowing at 12 l/hr fed the marsh although the pan dried in summer. *See* Wadien (1984).
Site 3. Fresh water. Rainfall provided water in spring and autumn but in summer the black mud pan dried up.
Site 4. Salt spring. The site did not exist 50 years ago. With recent increases in flow rate, currently 1380 l/hr the barren pan has expanded to 22 hectares. *See* Petch (1987) and Wadien (1984).
Site 5. Salt marsh. A dugout on the edge of a salt marsh. It remained filled with water in summer but froze over in winter.
Site 6. Salt marsh. Covering about 2 hectares it consisted of a series of pools 3-8 cm deep separated by low hummocks of salt tolerant plants. Seepage maintained the marsh and a saline slush indicated continual flow in winter.
Site 7. Salt seep. On Lake Winnipegosis shore, a series of seeps dried up in summer. *See* Cameron (1949) and Petch (1987).
Site 8. Salt seep. The flow of 180 l/hr off the limonite coated gravel pan decreased during the summer when most of the runoff evaporated. *See* Cameron (1949).
Site 9. Fresh water. A fresh water stream flowing through a grassy meadow gained runoff from Site 8. Flow was 900 l/hr but in the summer the site almost dried up.
Site 10. Salt seep. A series of small seeps about 5 cm deep on a limonite pan with a combined flow of 300 l/hr. The site froze in winter. *See* Tyrrell (1892) and Cole (1915).
Site 11. Salt marsh. A small depression about 3 m by 7 m devoid of vegetation and downstream from Sites 12 and 14. The site dried up in 1989 and froze in winter.
Site 12. Salt marsh. A barren pan about 15 m by 40 m with 5 cm of water in spring. No seep was found. It dried up in summer.
Site 13. Fresh water. About 1 hectare in area with 5 cm of water covering a muddy pan. It almost dried up in summer.
Site 14. Fresh water. A pool 10 m by 2 m and 20 cm deep upstream from Site 11. It dried up in 1989 and froze in winter.
Site 15. Salt spring. Three small springs separated by hummocky sections on the shore of Lake Winnipegosis. With a flow of 1500 l/hr the springs remained open in winter while 20 m downstream a ice slurry formed and further along this froze.
Site 16. Salt spring. A major spring on a large 0.3 sq km red limonitic pan. With a flow of 4800 l/hr and the TDS‰ of 61.6‰ the water remains similar to that noted in earlier studies. The site remained open in winter. *See* Cole (1915) and Cameron (1949).
Site 17. Salt marsh. This site is across a fresh water marsh from Site 11. Since source waters are a combination of salt and fresh waters these sites are similar. The salt water is from Site 16 via Site 18 and the freshwater is from the same source as that feeding Site 11. However Site 17 did not dry up in summer. It froze in winter.
Site 18. Salt spring. Downstream 500 m from Site 16. Effluent from Site 16 and a second major spring served as sources. The flow rate was about 11000 l/hr and an algal mat coated the red limonite streambed. The site froze in winter.
Site 19. Fresh water. This stream represented the combined effluent from sites 11, 12, 14, 16, 17 and 18. Although permanent the flow was reduced in summer and the site froze in winter.
Site 20. Salt spring. Located on the shore of Lake Winnipegosis. The flow (2700 l/hr) was rapid and rose about 20 cm above the red stained sinter pan. Gas bubbles were noted rising in the lake just offshore indicating the presence of underwater springs nearby. *See* Tyrrell (1892).
Site 21. Salt seep. Extending 30 m from the shore of Lake Winnipegosis the site rises steeply to the east. Near the top a small seep flowed at 60 l/hr. This evaporated before reaching the lake in summer. The flow has varied considerably over the years. *See* Cole (1915) and Cameron (1949).
Site 22. Salt spring. About 100 m from and 15 m above Lake Winnipegosis a cone of red stained sinter sediment approximately 1 m in height and 3 m in diameter serves as the source cauldron. Rates of flow have increased from 6780 l/hr as found by Tyrrell (1892), to 12360 l/hr (Cole 1915) and 15780 l/hr (Cameron 1949) while we found the flow to be 16320 l/hr.
Site 23. Salt spring. Flowing downhill over a red limonite pan the effluent from Site 22 broke into numerous tributaries. Some of these rejoin just before entering the Lake at Site 23. In summer some of the smaller tributaries dried up but small springs on the hill side apparently offset this loss as no reduction in flow was evident here.

than exist today. The extremes included the mesosaline spring Sites 4 and 15 which had the lightest isotope values while salt seep Site 7, subject to frequent drying, had the heaviest value.

Gases (Table 5 and 6)

Gas bubbles were frequently observed rising from spring cauldrons. Nitrogen was the major constituent (averaging about 96% by volume) while helium was up to 3000 times atmospheric levels (Table 5). Dissolved gases in spring waters showed preferential degassing of helium and nitrogen and those taken through the peat surface, sites 10s and 15s, showed that a loss of helium had taken place through the peat (Table 6).

Water Temperature (Table 7)

Low water temperatures were the norm at spring and seep sites but these rapidly approached ambient air temperatures a few metres downstream. At sites of rapid discharge, 4, 20 and 22, water temperature varied little throughout the year with a mean of 6.2°C. Site 16 was atypical in that although a rapid flow was evident the temperature increased to a high of 16°C in mid-summer, a result of warming in the large cauldron. In winter the water temperature near

TABLE 4. Water quality data

Site	Cl^- mg/l	Na^+ mg/l	K^+ mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	SO_4^{2-} mg/l	HCO_3^- mg/l	NH_3–N mg/l	Fe^{2+} mg/l	Mn^{2+} mg/l	pH units	Cond µmho/cm	Turb NTU	F^- mg/l	Colour Units	$CaCo_3$ mg/l	Hard mg/l	NO_3+NO_2–N mg/l	PO_4^{3-} mg/l	∫D ‰smow	∫^{18}O ‰smow
1	7175	4160	150	718	270	2265	242	0.6	1.39	.10	7.95	23600	33.3	1.17	32.5	198	2905	0.01	0.41		
2	9650	5568	117	668	206	1693	218	0.27	1.30	.15	8.0	25500	16.7	0.68	41.7	179	2517	0.13	0.34	-148.2	-19.67
3	3400	1975	32	220	112	500	264	0.07	0.10	.02	8.4	11500	2.0	0.17	50.0	224	1010	0.01	0.11		
4	17500	10650	320	1068	216	2510	255	2.8	3.41	.08	6.95	48800	20.0	2.19	5.0	209	3555	2.19	0.06	-151.4	-19.87
4D	25700	16100	407	1400	406	3600			0.79	.04	7.9	64000							0.21		
5	4560	2750	85	280	140	665	461	0.1	0.15	.04	8.0	14100	5.5	0.78	40.0	378	1280	0.01	0.05		
6	10000	6000	190	495	136	1940	163	0.05	0.34	.05	7.4	30000	0.9	3.30	12.0	134	1800	0.24	0.07		
7	23100	14233	370	1347	423	3493	290	0.64	1.84	.14	7.55	63800	12.7	2.69	9.0	238	5110	0.10	0.07	-105.5	- 9.82
8	28400	16200	350	1113	328	2478	214	3.0	13.35	.12	7.65	74300	17.2	0.40	5.0	175	4128	0.58	0.07	-144.6	-18.94
9	2180	1450	28	146	47	165	185	0.06	1.75	.02	7.75	4500	5.3	0.01	50.0	152	558	0.03	0.03		
10	30000	18800	475	1030	180	2650	139	0.48	1.63	.07	8.15	72700	8.4	0.60	5.0	114	3320	1.40	0.03	-145.7	-19.11
11	5850	3550	58	308	127	460	364	0.08	0.50	.32	7.15	17300	3.1	0.18	50.0	298	1295	0.01	0.07		
12	15800	9700	N/A	745	216	1700	237	0.03	0.51	.10	7.8	45500	1.3	0.25	15.0	194	2750	0.03	0.20		
13	3850	1184	21	130	66	78	438	0.07	0.13	.03	8.0	850	1.4	0.33	50.0	359	598	0.73	0.05		
14	3580	2162	5	241	75	606	161	0.05	0.56	.10	7.8	10369	2.4	0.12	50.0	132	909	0.15	0.05		
15	17550	10850	268	868	283	1625	206	2.83	3.97	.07	7.0	47500	6.6	0.64	5.0	169	3820	0.05	0.15	-153.6	-20.08
16	33500	21350	550	1188	250	3050	365	4.44	2.84	.06	6.9	82000	13.1	1.11	5.0	299	3998	0.23	0.03	-142.7	-17.95
17	17040	10115	25	587	132	1500	143	0.25	0.64	.05	8.1	41285	2.0	0.53	27.5	125	1966	0.19	0.04		
18	33600	20000	N/A	1210	240	3050	188	1.40	0.16	.03	8.15	80100	0.3	1.05	5.0	154	4010	0.37	0.02		
19	861	587	15	59	19	100	120	0.05	0.24	.05	7.8	3141	0.8	0.13	50.0	98	224	0.02	0.03		
20	33750	21313	460	1203	259	2940	377	4.44	5.15	.05	6.8	82650	10.1	1.22	5.0	309	4075	0.01	0.03	-136.5	-18.14
21	28300	16600	315	1000	249	2360	209	0.14	2.55	.06	8.1	69900	14.0	0.92	38.5	185	3523	0.37	0.48	-127.4	-15.29
22	33533	20100	535	1373	297	3073	387	4.45	2.34	.07	6.8	79533	14.0	1.19	5.0	317	4653	0.01	0.02	-140.6	-18.13
23	33533	20000	555	1360	303	3157	373	3.75	6.19	.30	7.55	79600	1.7	1.15	5.0	305	4650	0.34	0.02		

Table 5. Volume % composition of free gas bubbles in springs.

Station	4	16	15
He	0.54	1.52	0.40
CH_4	0.03	0.02	0.03
N_2	97.0	95.0	96.7
O_2	0.1	0.95	0.87
Ar	1.1	0.81	1.14
CO_2	1.26	1.75	0.89

Table 6. Volume % Composition Dissolved Gas In Springs

Station	4	15	16	10s	15s (sub-surface)
H_2	<0.01	0.01	<0.01	0.01	0.03
He	0.14	0.24	0.07	<0.03	<0.01
CH_4	<0.01	0.03	<0.05	<0.01	<0.01
N_2	58.1	70.3	55.0	33.6	66.0
O_2	0.05	0.02	1.76	0.01	0.05
Ar	1.44	1.84	1.20	0.76	1.52
CO_2	40.3	27.6	41.9	65.5	32.3

the bottom of the cauldron was 3.5°C but at the periphery it had fallen to 2°C. Downstream the temperature reached -4°C in the salt slush slurry near Site 18. Similar findings were noted at Site 4 in winter where the cauldron water was 5°C, at the snow boundary 0°C, and where slush formed -3°C.

Ion Ratios (Table 8 and 9)

Table 8 provides commonly compared milliequivalent/l ion ratios with those of Tyrrell (1892), Cole (1915), van Everdingen (1971), Wadien (1984) and Hem (1959). In general, the current data agree well with those of the other researchers. The Na/K ratio varies among authors but appears to be an aberration of low K measurements by Cole. The values gathered herein and those of Wadien (1984) are similar and close to that calculated for sea water. The Ca/Mg and Na+K/Ca+Mg ratios increase from fresh waters to the Hypersaline Dawson Bay salt springs, indicating the increased relative abundance of Ca to Mg and that of Na to the other cations. Nevertheless, the waters were deficient in Mg when compared to sea water.

Bromide to chloride ratios were determined for selected spring sites (Table 9) and compared to sea water and those calculated by Wadien (1984). Br/Cl ratios varied from 4.7 to 7.3 $\times$ 10^{-4} compared to 34.2 $\times$ 10^{-4} for sea water, indicating that the saline waters do not appear to represent concentrated residual marine waters.

Data comparisons (Table 10)

Our results are similar to those of Wadien (1984) suggesting stability of the water quality at these sites.

Biota

Ostracoda (Crustacea: Arthropoda) (Table 11 and 12)

Twenty-seven ostracode species were found, of which 16 were represented only by empty shells. Of the 11 species taken alive, eight were collected only

Table 7. Water Temperatures C°.

Site	1988 May	1988 July	1988 Aug	1988 Sept	1988 Nov	1989 July	1989 Nov	1990 Feb
4	7	7	6.2	6	6	7	6	5
4 ditch	n/s	n/s	n/s	n/s	n/s	27	0	-3
20	6	6	5.8	6	n/s	6.5	n/s	n/s
22	6.2	6.2	6	6	n/s	n/s	n/s	n/s
23	15	11	15	7	n/s	n/s	n/s	n/s
16	9.2	16	11	7	5	9	5	3.5
18	19.5	26	29	8.5	-2.3	25	-1	-4
15	n/s	10.5	8	6	5	9	3	2

TABLE 8. Ion ratios.

Site	Na/Cl	Na/K	Mg/Ca	Ca/Mg	$\frac{Na+K}{Ca+Mg}$	$\frac{Ca+Mg}{Na+K}$	SO_4/Cl
1	0.897	53.14	0.608	1.65	3.2	0.31	0.231
2	0.892	62.26	0.514	1.95	5.17	0.19	0.130
3	0.895	106.28	0.839	1.19	4.29	0.23	0.109
4	0.925	45.01	0.340	2.94	6.72	0.15	0.105
5	0.954	36.56	0.757	1.32	4.36	0.23	0.173
6	0.925	53.14	0.453	2.21	7.41	0.13	0.143
7	0.952	69.01	0.517	1.93	4.91	0.20	0.114
8	0.901	80.98	0.489	2.05	8.81	0.11	0.065
9	1.025	89.50	0.531	1.88	5.71	0.18	0.056
10	0.930	49.28	0.411	2.43	10.79	0.09	0.067
11	0.920	68.45	0.650	1.54	6.00	0.17	0.076
12	0.946	N/S	0.478	2.09	7.68	0.13	0.079
13	0.916	97.25	0.831	1.20	3.93	0.25	0.032
14	0.920	32.09	0.597	1.68	3.49	0.29	0.114
15	0.937	52.90	0.555	1.80	9.54	0 .10	0.068
16	0.958	53.70	0.373	2.68	11.52	0.09	0.067
17	0.962	47.65	0.430	2.33	9.03	0.11	0.069
18	0.910	23.76	0.385	2.60	11.01	0.09	0.067
19	0.984	42.21	0.540	1.85	6.34	0.16	0.074
20	0.974	85.03	0.356	2.81	11.46	0.09	0.065
21	0.904	80.98	0.395	2.53	10.29	0.10	0.062
22	0.924	68.28	0.357	2.80	9.52	0.11	0.068
23	0.919	63.53	0.369	2.71	9.49	0.11	0.070
Mean	0.933	61.87	0.512	2.09	7.42	0.157	0.091
Mean F Water	0.948	73.46	0.668	1.56	4.75	0.222	0.077
Mean S Marshes	0.928	53.53	0.556	1.87	6.12	0.181	0.129
Mean Seep&Springs	0.925	63.04	0.451	2.28	8.51	0.125	0.080
Mean DBay Springs	0.937	58.84	0.368	2.72	10.61	0.098	0.067
Cole (1915, pages 61 and 64, data from Site 16 (Site A) and 22 (Site C))							
Site 16 Cole	0.935	288.87	0.410	2.44	9.80	0.102	0.090
Site 22 Cole	0.919	307.1	0.418	2.39	10.49	0.095	0.065
Site 22 Tyrrell	0.945	26.31	0.422	2.37	10.37	0.097	0.068
van Everdingen (1971, page 348, data from Tyrrell 1892 and Cole 1915)							
Mean	0.954	1096.1	0.472	2.12	8.40	0.119	0.073
Mean Seep&Spring	0.915	30.9	0.532	1.88	8.13	0.123	0.066
Mean DBay Spring	0.941	139.7	0.424	2.36	9.90	0.101	0.069
Wadien (1984, pages 28-29, data from six saline springs)							
Mean	0.927	56.6	0.513	1.95	6.49	0.154	0.113
Site 2 SMarsh	0.967	64.18	0.459	2.18	6.82	0.147	0.09
Site 4 Seep&Spring	0.868	56.18	0.480	2.08	4.93	0.203	0.064
Hem (1959)							
Sea water	0.858	47.26	5.244	0.19	3.76	0.266	0.100

during one sampling period. Three species, *Limnocythere staplini, Cyprinotus salinus,* and *Candona rawsoni* were taken repeatedly at the same sites. Site 4 always had *L. staplini* while Site 5 had both *C. salinus* and *C. rawsoni* on three occasions. Interestingly, the June 1988 and July 1989 sample series showed all three species recurring at many of the same sites. The August sample at Site 14 contained specimens of *Cyclocypris serena, Cypridopsis vidua* and *Ilyocypris gibba* while Site 19 had *Cytheromorpha fuscata* and *Ilyocypris bradyi*. *Potamocypris unicaudata* was found at both Sites 14 and 19 in August. Earlier in June 1988 Site 2 contained immature *Cypridopsis aculeata* and at Site 13 *Candona renoensis* was taken in May.

Live *L. staplini* were found in all four water quality categories including the most saline site. Empty shells of all other species were found in much more saline waters than were the living representatives, possibly indicating that the species tolerance to salinity was exceeded. Live *C. salinus* and *C. rawsoni* were taken only in the fresh water and salt marsh categories although empty shells were found in all water categories. Live *C. aculeata* were taken in the salt marsh Site 2. Live of all other species were found only in fresh water sites. Three species,

Table 9. Bromide/Chloride ratios on specific samples.

Site	Br^- (mg/l)	Cl^- (g/l)	Br^-/Cl^- X 10^4	TDS‰	Sal‰
7	11	20.5	5.36	45.7	38.8
20	22	34.0	6.47	62.5	60.3
21	20	31.0	6.45	66.9	67.3
22	16	34.0	4.71	61.2	56.9
4(Wadien)	9.9	18.7	5.31	35.8	33.7
2(Wadien)	7.9	10.8	7.27	19.8	19.5
sea water	65	18.98	34.24	34.4	34.3

Candona acutula, Cyprinotus incongruens and *Limnocythere inopinata*, were restricted to fresh water and in this study only empty shells were taken. It is probable that viable colonies have not survived because of the ephemeral nature of Sites 14 and 19 and the intolerance of these species to sodium levels above 320, 750 and 207 mg/l respectively (Delorme, personal files).

Neale and Delorme (1985) provided physico-chemical ranges from the Manitoba lakes area for *C. fuscata*, a coastal marine species. While current results fall well within the given ranges for most parameters, some extremes were noted including sodium, 587 mg/l vs their range (152-413); chloride, 861 mg/l vs (236- 637); TDS, 2475‰ vs (647-1400); conductivity, 3141 vs (1130- 2200); and pH, 7.8 vs (8.3-9.0). Interestingly, fossils of *C. fuscata* were recovered among the dead at Site 15 on the shore of Lake Winnipegosis and in Lake Winnipegosis near Site 20. These may represent material reworked from older marine-brackish water sediments within Lake Winnipegosis.

Forester (1983) indicates that *L. staplini* found in South Dakota had a salinity range of 0.2 - 43.3‰ whereas our range was 1.58-60.95‰. Comparing current findings with those of Delorme (1965, 1984) working on Saskatchewan $NaSO^4$ dominated lakes we find lower values for SO^4 (100-2940) vs 48700 mg/l, pH (6.8-8.1) vs (8.4-9.3) and Mg (19-423) vs an upper limit of 5928 mg/l; whereas our upper limit for Ca is greater (59-1347) vs 296 mg/l as it is for Na+K (602-21773) vs 15922 mg/l and Cl (861-33750) vs 4345 mg/l.

The salinity ranges for *C. rawsoni* (6.98-8.26‰) and *P. unicaudata* (1.58-6.49‰) lie well below the upper limits given by Delorme (1965) of 18.8‰ and 13.57‰ for prairie lakes. The pH values herein are lower and values of 8.0 and 7.8 were found compared to 8.4 and 8.5. Upper limits for calcium were greater (280 vs 168 and 241 vs 184 mg/l). On the other hand our upper Mg values of 140 and 75 mg/l were far less than the 1008 and 1070 mg/l previously reported as were the SO_4 values of 665 vs 10900 and 606 vs 3915 mg/l. Bicarbonate ranges of (438-461) and (120-161) were also less than the limits of 1479 and 1070 mg/l described by Delorme (1965). The

Table 10. Physico-chemical comparison between 1984 and 1988-1989.

Parameter		Site 4		Site 2	
		Wadien (her site 4)	Mean Current Study	Wadien (her site 5)	Mean Current Study
Water Temp.	C°	6	6.3	7.5	19.0
pH	units	7.1	6.9	7.2	8.0
Conductivity	µmho/cm	49500	48800	28490	25500
Na	mg/l	11700	10650	6080	5568
K	mg/l	310	320	184	117
K/Na ratio		0.027	0.030	0.030	0.021
Ca	mg/l	1041	1068	739	668
Mg	mg/l	290	216	215	206
Hardness ($CaCO_3$)	mg/l	3794	3555	2730	2517
SO_4	mg/l	2461	2510	930	1693
Alkalinity (Total)	mg/l	212	209	208	179
Cl	mg/l	18650	17500	10800	9650
Filt residue (TDS)	mg/l	35790	35000	19810	19633
F	mg/l	2.15	2.19	1.5	0.68
Fe	mg/l	0.189	3.41	0.067	1.3
Mn	mg/l	0.032	0.08	0.032	0.15
As	mg/l	0.0267	< 0.3	0.0031	< 0.3
Cu	mg/l	< 0.01	< 0.05	< 0.01	< 0.05
Ni	mg/l	0.084	< 0.06	0.093	< 0.06
Pb	mg/l	0.078	< 0.28	< 0.05	< 0.28
Sr	mg/l	14.90	15.4	10.40	13.1
Zn	mg/l	0.041	0.013	0.054	< 0.046

TABLE 11. Distribution of Ostracoda.

Species	Sites
Candona rawsoni Tressler	5, 13
Candona rawsoni (dead)	2, 5, 13, 15, 21, 23, Lake Winnipegosis
Candona renoensis Gutentag and Benson	13
Candona renoensis (dead)	13, 17, 18, 23
Cyclocypris serena (Koch)	14
Cyclocypris serena (dead)	2, 14, 15
Cypridopsis aculeata (Liljeborg)	2
Cypridopsis aculeata (dead)	2, 11, 23
Cypridopsis vidua (Muller)	14
Cypridopsis vidua (dead)	2, 5, 13, 14, 19, 20, 23, L.Winnipegosis
Cyprinotus salinus Brady	2, 5, 14, 19
Cyprinotus salinus (dead)	2, 5, 6, 7, 8, 9, 11, 13, 14, 17, 19, 23
Cytheromorpha fuscata (Brady)	19
Cytheromorpha fuscata (dead)	15, 19, 20,L.Winnipegosis
Cytheromorpha fuscata (fossil)	15, L.Winnipegosis
Ilyocypris bradyi Sars	19
Ilyocypris bradyi (dead)	5, 15, 19
Ilyocypris gibba (Ramdohr)	14
Ilyocypris gibba (dead)	14, 15, 19, 23
Limnocythere staplini Gutentag & Benson	1, 4, 5, 6, 7, 9, 10, 11, 15, 19, 20, L.Winnipegosis
Limnocythere staplini (dead)	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 13,14,15 16, 17, 18, 19, 20, L.Winnipegosis
Potamocypris unicaudata Alm	14, 19
Potamocypris unicaudata (dead)	2, 13, 14, 19
Dead	
Candona acuta Hoff	15
Candona acutula Delorme	14, L.Winnipegosis
Candona compressa (Kock)	13, 17, L.Winnipegosis
Candona distincta Furtos	17, L.Winnipegosis
Candona ohioensis Furtos	2, L.Winnipegosis
Cyclocypris ampla Furtos	2, 14, 17, 20, 23, L.Winnipegosis
Cyclocypris sharpei Furtos	2, 14, 23, L.Winnipegosis
Cypria ophthalmica (Jurine)	2
Cyprinotus carolinensis Ferguson	9, 17
Cyprinotus glaucus Furtos	15, 23
Cyprinotus incongruens (Ramdohr)	19
Cyprois marginata (Strauss)	13, 17
Limnocythere ceriotuberosa Delorme	15
Limnocythere inopinata (Baird)	19
Limnocythere itasca Cole	15, L.Winnipegosis
Megalocypris ingens Delorme	6, 11

Na+K ranges of (1205-2835) and (602-2167) were well below the upper limits of 5194 and 6537 mg/l. However Cl concentrations extended the limits of 1200 and 500 to 4560 and 3580 mg/l. Hammer (1986) noted that *Cypridopsis aculeata* and *I. gibba* have been found at salinities up to 10‰. In the current study living *C. aculeata* were found at a mean salinity of 17.45‰ and empty shells between 10.59-60.56‰. We found I. gibba at 6.49‰, well below the 10‰ figure and for *C. salinus* (1.58-17.45‰) extended the range below that given by Hammer (1986) as (10-59.4‰). Delorme (1965) classified *Cyprinotus glaucus* as having an upper salinity tolerance of 12‰. TDS which may explain why only empty shells were found in the saline sites 15 and 23 in the current study.

Hammer (1986) noted that live *Cyclocypris ampla* were found but once in a single lake while we found empty shells in a variety of habitats but no live specimens; and that *L. inopinata* was found only in fresh water, which parallels our finding it, albeit dead, in Site 19 the least saline site. *L. inopinata* may be sensitive to sodium and chloride and like *C. incongruens* has been collected only in fresh waters. Apparently the former is characteristic of such waters preferring low turbidity, chloride, alkalinity and conductivity.

Cladocera and Copepoda (Crustacea: Arthropoda) (Table 13 and 14)

Previous study by Hammer (1986) and Moore (1952) has shown that salinity plays an important role in entomostracan distribution. The cladocerans *Daphnia pulex* and *Moina rectirostris* were collected in waters of 16.8‰ and 19.6‰ TDS respectively. *Acroperus harpae* and *Eurycercus lamellatus* were found only in the fresh water Site 19 at 2.5‰ TDS while *Polyphemus pediculus* was taken in Lake Winnipegosis near Site 20. Moore (1952) in Saskatchewan lakes took *A. harpae* in a TDS range from 0.370 to 0.449‰, *E. lamellatus* from 0.370 to 1.267‰, *P. pediculus* from 0.370 to 0.864‰ and *D. pulex* from 0.45 to 13.2‰. Hammer (1986) noted that *M. rectirostris* has been found in African and European saline waters ranging from 3 to 10‰ salinity while we extended this upward to 17.5‰.

Hammer (1986) gives salinity ranges for the copepods *Acanthocyclops vernalis* as 3-10‰ and *Diacyclops (bicuspidatus) thomasi* as 3-107‰. Our findings broadened the range for *A. vernalis* to 1.6-28.6‰. Moore (1952) indicated that *Diaptomus siciloides* was taken in lakes ranging from 0.625-106.7‰ TDS but Hammer considered the species determination an error and that *D. siciloides* should not be considered a saline species. This is in keeping with our finding it in waters up to only 16.8‰. The harpacticoid *Cletocamptus albuquerquensis* was found in all water categories and TDS ranged from 2.5-65.2‰. Extreme variation in gross morphology, probably related to the wide salinity range, made identification difficult. Hammer (1986) gives a salinity range for this species as 4->300‰ the largest for any entomostracan and Loffler *in* Hammer (1986) suggested that the salinity optima may differ among ecotypes.

Insecta and Arachnida (Arthropoda)

Adult *Cingilia catenaria* Drury, the Chain-Dotted

Table 12. Ostracoda distribution relative to physico-chemical parameters.

Species	Filterable Residue TDS mg/l	Salinity ‰	pH units	SO_4 mg/l	Na+K mg/l	Ca mg/l	Mg mg/l	Cl mg/l	HCO_3 mg/l
Candona rawsoni	4275-9140	6.98-8.26	8.0	78-665	1205-2835	130-280	66-140	3850-4560	438-461
C. rawsoni (d)	4275-60833	6.98-60.56	7.0-8.1	78-3157	1205-20555	130-1360	66-303	3850-33533	206-461
Candona renoensis	4275	6.98	8.0	78	1205	130	66	3850	438
C. renoensis (d)	4275-61700	6.98-60.68	7.5-8.1	78-3157	1205-20555	130-1360	66-303	3850-33600	143-438
Cyclocypris serena	6985	6.49	7.8	606	2167	241	75	3580	161
C. serena (d)	6985-34300	6.49-31.71	7.0-8.0	606-1693	2167-11118	241-868	75-283	3580-17550	161-218
Cypridopsis aculeata	19633	17.45	8.0	1693	5685	668	206	9650	218
C. aculeata (d)	11000-60833	10.59-60.56	7.1-8.0	460-3157	3608-20555	308-1360	127-303	5850-33533	218-373
Cypridopsis vidua	6985	6.49	7.8	606	2167	241	75	3580	161
C. vidua (d)	2475-63150	1.58-60.95	6.8-8.0	78-3157	602-21773	59-1360	19-303	861-33750	120-461
Cyprinotus salinus	2475-19633	1.58-17 45	7.8-8.0	100-1693	602-5685	59-668	19-206	861-9650	120-461
C. salinus (d)	2475-60833	1.58-60.56	7.1-8.1	78-3157	602-20555	59-1360	19-423	861-33533	120-461
Cytheromorpha fuscata	2475	1.58	7.8	100	602	59	19	861	120
C. fuscata (d)	2475-63150	1.58-60.95	6.8-7.8	100-2940	602-21773	59-1203	19-259	861-33750	120-377
Ilyocypris bradyi	2475	1.58	7.8	100	602	59	19	861	120
I. bradyi (d)	2475-34300	1.58-31.71	7.0-8.0	100-1625	602-11118	59-862	19-283	861-17550	120-461
Ilyocypris gibba	6985	6.49	7.8	606	2167	241	75	3580	161
I. gibba (d)	2475-60833	1.58-60.56	7.0-7.8	100-3157	602-20555	59-1360	19-303	861-33533	120-373
Limnocythere staplini	2475-63150	1.58-60.95	6.8-8.1	100-2940	602-21773	59-1247	19-423	861-33750	120-461
L. staplini (d)	2475-63150	1.58-60.95	6.8-8.1	78-3493	602-21900	59-1347	19-423	861-33750	120-461
Potamocypris unicaudata	2475-6985	1.58-6.49	7.8	100-606	602-2167	59-241	19-75	861-3580	120-161
P. unicaudata (d)	2475-19633	1.58-17.45	7.0-8.0	100-1693	602-5685	59-668	19-206	861-9650	120-438
Candona acuta (d)	34300	31.71	7.0	1625	11118	868	283	17550	206
Candona acutula (d)	6985	6.49	7.8	606	2167	241	75	3580	161
Candona compressa (d)	4275-31080	6.98-30.79	8.0-8.1	78-1500	1205-10140	130-587	66-132	3850-17040	143-438
Candona distincta (d)	31080	30.79	8.1	1500	10140	587	132	17040	143
Candona ohioensis (d)	19633	17.45	8.0	1693	5685	668	206	9650	218
Cyclocypris ampla (d)	6985-63150	6.49-60.95	6.8-8.1	606-3157	2167-21773	241-1360	75-303	3580-33750	143-377
Cyclocypris sharpei (d)	6985-60833	6.49-60.56	7 0-8.0	606-3157	2167-20555	241-1360	75-303	3580-33533	161-373
Cypria ophthalmica (d)	19633	17.45	8.0	1693	5685	668	206	9650	218
Cyprinotus carolinensis (d)	3300-31080	3.96-30.79	7.7-8.1	165-1500	1478-10140	146-587	47-132	2180-17040	143-185
Cyprinotus glaucus (d)	34300-60833	31.71-60.56	7.0-7.5	1625-3157	11118-20555	868-1360	283-303	17550-33533	206-373
Cyprinotus incongruens (d)	2475	1.58	7.8	100	602	59	19	861	120
Cyprois marginata (d)	4275-31080	6.98-30.79	8.0-8.1	78-1500	1205-10140	130-587	66-132	3850-17040	143-438
Limnocythere ceriotuberosa (d)	34300	31.71	7.0	1625	11118	868	283	17550	206
Limnocythere inopinata (d)	2475	1.58	7.8	100	602	59	19	861	120
Limnocythere itasca (d)	34300	31.71	7.0	1625	11118	868	283	17550	206
Megalocypris ingens (d)	11000-20400	10.59-18.08	7.1-7.4	460-1940	3608-6190	308-495	127-136	5850-10000	163-364

(d)=dead*

TABLE 13. Distribution of Entomostraca.

Species	Sites
Cladocera	
Acroperus harpae Baird	19
Eurycercus lamellatus (Muller)	19
Daphnia pulex (de Geer)	1
Moina rectirostris Jurine	2, 3
Polyphemus pediculus (Linne)	LW
Copepoda	
Calanoida	
Diaptomus siciloides Lilljeborg	1, LW
Cyclopoida	
Acanthocyclops vernalis (Fischer)	1, 2, 3, 11, 12, 19
Diacyclops (bicuspidatus) thomasi Forbes	21, 22, LW
Harpacticoida	
Cletocamptus albuquerquensis (Herrick)	1, 2, 3, 4, 5, 7, 9, 10, 12, 13, 16, 19, 21, 22

Geometer, were taken at Sites 12 and 15 on 19 September 1989 while in July larvae of these moths had been collected feeding on *Triglochin maritima*. Dipteran larvae of the family Syrphidae were taken at Sites 9 and 6 on 19 July 1989. The Water Boatman *Trichocorixa verticalis interiores* Sailer was collected on 19 July 1989 at Site 6. Tones and Hammer (1975) indicated that this species is particularly successful in saline water in Saskatchewan. The mean salinity at Site 6 was 18.1‰ in keeping with the earlier records.

Juvenile and adult salticid jumping spiders *Eris pinea* (Kaston) were obtained at Site 14 on 19 July 1988. On 20 July 1988 an immature wolf spider *Arctosa* sp. was taken at Site 6.

Rotifera (Table 15 and 16)

The rotifer assemblages consisted mainly of common species with wide tolerance limits and thus of limited indicator value. The extreme and fluctuating physico-chemical conditions also allowed sporadic occurrence of many species at a variety of sites. The most frequently taken species was the characteristically euryhaline *Brachionus plicatilis* found in brackish and marine environments; in our samples it was found 16 times, sometimes as the only rotifer and usually in very large numbers. *Brachionus pterodinoides*, on the other hand, was a remarkable find at Site 5. This species is very rare, reported by Chengalath and Koste (1987) from small vegetation free eutrophic ponds at pH 9.5 in northwest Canada, and by Ahlstrom (1940) from highly alkaline habitats in North Dakota, British Columbia, Mexico and Argentina. Interestingly, although the pH at Site 5 was only 8.0, it was the most alkaline habitat studied. In addition to the salt water species *Colurella dicentra* and *Hexarthra fennica*, a new *Lecane (Monostyla)* sp. was found which is being described by Nogrady and McKillop (in preparation). This species was collected in especially large numbers in August. *Notholca squamula*, found in several locations, is a rather common species. Its high salt tolerance in these habitats is unusual, and one would have expected it to be replaced by *Notholca salina*, which was not found in the current study. Another surprising find was *Notholca laurentiae* in the salt marsh Site 2 as this species was previously thought to be restricted to the St. Lawrence Great Lakes.

Foraminifera (Sarcodina: Protozoa) (Table 17 and 18)

Four foraminiferal species and nine arcellaceans were identified from 19 sites. *Jadammina*

TABLE 14. Entomostraca distribution relative to salinity and filterable residue

Species	Hammer Salinity ‰	Moore TDS ‰	Current Study Salinity ‰	TDS‰
A.h.		0.37 – 0.45	1.6 2.5	
E.l.		0.37 – 1.3	1.6 2.5	
D.p.	5 – 30	0.45 – 13.2	13.0 16.8	
M.r.	3 – 10	0.65 – 1.0	6.2 – 17.5	7.5 – 19.6
P.p.		0.37 – 0.86	LW	LW
D.s.	none saline	0.63 – 106.7	LW – 13.0	LW – 16.8
A.v.	3 – 10		1.6 – 28.6	2.5 – 31.8
D.b.t.	3 – 107	0.3 – 106.7	LW – 60.6	LW – 65.2
C.a.	4 – >300	18.7 – 106.7	1.6 – 60.6	2.5 – 65.2

Table 15. Distribution of Rotifera.

Species	Sites
Brachionus angularis Gosse	L. Winnipegosis
Brachionus plicatilis Muller	1, 2, 5, 6, 11, 18, 19
Brachionus pterodinoides Rousselet	5
Brachionus quadridentatus Hermann	5
Cephalodella forficula (Ehrbg.)	19
Colurella colurus (Ehrbg.)	2, 9, 11
Colurella dicentra (Gosse)	2, 6
Colurella uncinata (Muller)	5, 9
Euchlanis dilatata Ehrbg.	L. Winnipegosis
Euchlanis incisa Carlin	19
Filinia longiseta (Ehrbg.)	L. Winnipegosis
Filinia terminalis (Plate)	L. Winnipegosis
Gastropus stylifer Imhof	21, L. Winnipegosis
Hexarthra fennica (Levander)	5
Kellicottia longispina (Kellicott)	10, L. Winnipegosis
Keratella cochlearis (Gosse)	10, 17, 19, 21, L. Winnipegosis
Keratella crassa Ahlstrom	10, L.Winnipegosis
Keratella earlinae Ahlstrom	L. Winnipegosis
Keratella quadrata canadensis Berzins	10
Keratella quadrata frenzeli (Muller)	2, 10, L. Winnipegosis
Lecane (Monostyla) new sp.	5
Lecane (Monostyla) lunaris (Ehrbg.)	13, 19
Lepadella ovalis (Muller)	5
Lepadella patella (Muller)	5,13,19
Notholca acuminata (Ehrbg.)	2, 3, 5, 6, 9, 11, 19
Notholca foliacea (Ehrbg.)	19
Notholca laurentiae Stemberger	2
Notholca squamula (Muller)	10, L. Winnipegosis
Ploesoma truncatum (Levander)	L. Winnipegosis
Polyarthra euryptera Wierzejski	L. Winnipegosis
Polyarthra remata Skorikov	L. Winnipegosis
Polyarthra vulgaris Carlin	L. Winnipegosis
Pompholyx sulcata Hudson	L. Winnipegosis
Synchaeta pectinata Ehrbg.	2, L. Winnipegosis
Synchaeta stylata Wierzejski	L. Winnipegosis
Testudinella elliptica (Ehrbg.)	1, 2, 6, 15, L. Winnipegosis
Trichocerca (D.) rousseleti (Voigt)	L. Winnipegosis
Trichotria tetractis (Ehrbg.)	19

macrescens was found in most sites and at salt seep Site 21 live *J. macrescens* phenotype polystoma was also taken. Other species included *Polysaccammina ipohalina, Miliammina fusca*, and a new species, *Annectina viriosa*, described by Patterson and McKillop (1991). Live specimens of *P. ipohalina* and *A. viriosa* were found at sites 3 and 6 respectively. No live *M. fusca* were obtained. Foraminifera were found in all sites other than four hypersaline Dawson Bay salt springs (sites 16, 18, 22, and 23). The environment at these sites is not unlike that of Site 20, where empty tests of both *J. macrescens* and *M. fusca* were found. However, Site 20 is within a few metres of Lake Winnipegosis and thus subject to contamination through wave wash.

Like the foraminifera, the arcellaceans were represented in all environmental categories including the Lake Winnipegosis site. However, only two species, namely *Centropyxis constricta* and *Difflugia corona*, were taken alive and these were in fresh water. Additional species and water chemistry correlation is provided in Patterson et al. (1990).

Gastropoda and Pelecypoda (Mollusca) (Table 19)

Molluscs were taken at Sites 15, 14, 13, 9, 5 and at Site 7 where Petch (1987) had previously found dead *Helisoma anceps anceps* and *Stagnicola elodes*. We found no live specimens at either of the mesosaline Sites 15 and 7. Hammer (1986) provided salinity ranges for *Stagnicola elodes* (Say) = *Lymnaea palustris* (Muller) as 3-10‰TDS and for *L. stagnalis* as 3-4‰TDS. Our study broadened the range only for the latter to 7.0‰TDS.

Aves (Chordata) (Table 20)

Migratory bird species known to frequent coastal marshes were observed on the salt marshes, salt

TABLE 16. Rotifera distribution relative to physico-chemical parameters.

Species	Filterable Residue TDS ‰	Salinity ‰	pH units	SO_4 mg/l	Na+K mg/l	Ca mg/l	Mg mg/l	Cl mg/l	HCO_3 mg/l
B. angularis	Lake Winnipegosis								
B. plicatilis	2.5-61.7	1.6-60.7	7.1-8.1	100-3050	602-20000	59-1210	19-270	861-33600	120-461
B. pterodinoides	9.1	8.3	8.0	665	2835	280	140	4560	461
B. quadridentatus	9.1	8.3	8.0	665	2835	280	140	4560	461
C. forficula	2.5	1.6	7.8	100	602	59	19	861	120
C. colurus	3.3-19.6	4.0-17.5	7.1-8.0	165-1693	1478-5685	146-668	47-206	2180-9650	185-364
C. dicentra	19.6-20.4	17.5-18.1	7.4-8.0	1693-1940	5685-6190	495-668	136-206	9650-10000	163-218
C. uncinata	3.3-9.1	4.0-8.3	7.7-8.0	165-665	1478-2835	146-280	47-140	2180-4560	185-461
E. dilatata	Lake Winnipegosis								
E. incisa	2.5	1.6	7.8	100	602	59	19	861	120
F. longiseta	Lake Winnipegosis								
F. terminalis	Lake Winnipegosis								
G. stylifer	50.8	51.1	8.1	2360	16915	1000	249	28300	209
H. fennica	9.1	8.3	8.0	665	2835	280	140	4560	461
K. longispina	56.6	54.2	8.1	2650	19275	1030	180	30000	139
K. cochlearis	2.5-56.6	1.6-54.2	7.8-8.1	100-2650	602-19275	59-1030	19-249	861-30000	120-209
K. crassa	56.6	54.2	8.1	2650	19275	1030	180	30000	139
K. earlinae	Lake Winnipegosis								
K. q. canadensis	56.6	54.2	8.1	2650	19275	1030	180	30000	139
K. q. frenzeli	19.6-56.6	17.5-54.2	8.0-8.1	1693-2650	5685-19275	668-1030	180-206	9650-30000	139-218
L. new sp.	9.1	8.3	8.0	665	2835	280	140	4560	461
L. lunaris	2.5-4.3	1.6-7.0	7.8-8.0	78-100	602-1205	59-130	19-66	861-3850	120-438
L. ovalis	9.1	8.3	8.0	665	2835	280	140	4560	461
L. patella	2.5-9.1	1.6-8.3	7.8-8.0	78-665	602-2835	59-280	19-140	861-4560	120-461
N. acuminata	2.5-20.4	1.6-18.1	7.1-8.4	100-1940	602-6190	59-668	19-206	861-10000	120-461
N. foliaceae	2.5	1.6	7.8	100	602	59	19	861	120
N. laurentiae	19.6	17.5	8.0	1693	5685	668	206	9650	218
N. squamula	56.6	54.2	8.1	2650	19275	1030	180	30000	139
P. truncatum	Lake Winnipegosis								
P. euryptera	Lake Winnipegosis								
P. remata	Lake Winnipegosis								
P. vulgaris	Lake Winnipegosis								
P. sulcata	Lake Winnipegosis				5685	668	206	9650	218
S. pectinata	19.6	17.5	8.0	1693					
S. stylata	Lake Winnipegosis								
T. elliptica	16.8-34.3	13.0-31.7	7.0-8.0	1625-2265	4310-11118	495-868	136-283	7175-17550	163-242
T. rousseletti	Lake Winnipegosis								
T. tetractis	2.5	1.6	7.8	100	602	59	19	861	120

Table 17. Distribution of Foraminifera and Arcellaceans.

Species	Sites
Foraminifera	
Jadammina macrescens (Brady)	1*, 2, 3*, 4, 5, 6, 7, 8, 9, 10*, 11*, 12, 13, 14, 15, 17*, 19, 20, 21*
Jadammina macrescens phenotype: polystoma	1,3,6,7,21*
Miliammina fusca (Brady)	20
Polysaccammina ipohalina Scott	2,3*,5,6,10,11,17
Annectina viriosa Patterson and McKillop	6*
Arcellaceans	
Centropyxis aculeata (Ehrenberg)	1,2,4,9,17,20
Centropyxis constricta (Ehrenberg)	9*,13,17, Lake Winnipegosis
Cucurbitella tricuspis (Carter)	2,11,17
Difflugia corona Wallich	7, Lake Winnipegosis*
Difflugia globulus (Ehrenberg)	7,9
Difflugia oblonga (Ehrenberg)	7,9,13,20
Difflugia protaeiformis Lamarck	6
Heleopera sphagni (Leidy)	9
Pontigulasia compressa (Carter)	9

* (includes live in addition to dead specimens)

seeps and salt springs. Neale and Delorme (1985) and Patterson et al. (1990), believe birds are responsible for transporting the many small marine and brackish water invertebrates into the area from the Gulf of Mexico and Hudson Bay.

Discussion

Slight variations may result from preferential Br concentration by shale ultra-filtration, but the relatively constant Br/Cl ratio found in the current study and by Wadien (1984) indicates that the brines of the saline waters have a common source. The Br/Cl values are very similar to those reported for formation water samples of similar TDS associated with the deeper oil wells of the southwestern Manitoba sedimentary basin. Betcher (1991, personal communication) has indicated that the major ion geochemistry of the spring waters is nearly identical to the basin brines of similar TDS. These brines can be assumed to have a similar origin, and from regional hydrodynamics it appears that the springs represent discharge sites for the deep sedimentary basin brines moving from the southwest.

A significant portion of these waters represent isotopically depleted sub-glacial waters that were injected and mixed with existing brines in the Devonian and older carbonate rock aquifers during the Pleistocene. The "lighter" isotopic composition indicates that the waters are not strictly of marine origin but rather a mixture stemming from at least two sources. The deep area groundwaters flowing northward from the recharge sites several hundred kilometres to the southwest combine with archaic brines. In turn this brine mixture comes into contact and mixes with the Pleistocene injected waters. This water is presently being discharged at the hypersaline springs.

The mesosaline springs and seeps not only lack the high filterable residue levels of the hypersaline springs but appear to have distinct isotopic signatures. These waters were the "lightest" isotopically indicating that water injected during the Pleistocene is only now being flushed to the surface. Moreover, the land owner of Site 4 indicated that fifty years ago they had farmed the area but were forced to stop as the salt spring suddenly expanded. The pan currently covers over 22 hectares. At seeps, on the other hand, local infiltration of isotopically modern groundwater coupled with significant evaporation is suspected of lowering the isotopic values. In addition, this water may be further altered by salt dissolution from near surface strata by modern groundwater recharge.

Besides the elevated chloride concentration and the much reduced levels of sulphate and magnesium, the pH range was much lower than that associated with the sulphate dominated saline waters in central Canada. These factors play an important role in determining the associated biota.

Previous study by Delorme (1970, 1971a), Neale and Delorme (1985) and Nielsen et al. (1987) provided evidence that marine ostracodes were present in Lake Winnipegosis. *Cyprinotus salinus* and *Cytheromorpha fuscata* are commonly found living near coastal areas in various parts of the world but are only infrequently taken inland, while the remainder are brackish-freshwater species many of which are capable of tolerating fairly high total dissolved solids, particularly sulphate. Live *C. salinus* were collected from Lake Winnipegosis by Delorme (1970) and Holocene fossils of this species were recovered by Delorme (1971b) from the Sturgeon Lake terrace sediments representing deposition between 8550 and 9100 years B.P. It is noteworthy

that these sediments were heavily coated by limonite as are many of the spring sites as reported in the current study.

Neale and Delorme (1985) describe two possible explanations for the presence of these micro-invertebrates in Manitoba. They suggest the most probable mechanism is seeding by migrating water birds bringing ingested eggs or eggs in the mud on their feet. Alternately, the various species may be relicts from an earlier marine-brackish water basin.

During glaciation brackish water harbouring marine species may have been forced southward ahead of the glacier (Champagne et al. 1979). However this method of seeding is thought unlikely as many species of the various phyla found in the current study are unknown in the arctic, including Hudson Bay.

Five species of Cladocera and four copepods were found during the study. Moore (1952) suggested that cladocerans were more restricted by salinity than copepods, findings supported by our results. Copepods may also be restricted by lack of food, especially in the more saline habitats. The variable gross morphology of *Cletocamptus albuquerquensis* initially led to taxonomic confusion but with further study specimens were shown to be a series of morphs rather than new species. While it is probable that the gross morphology would differ among the variously adapted populations, the wide distribution pattern and salinity tolerance was unique.

Lepidoptera, Diptera, Hemiptera and Araneida were collected at various sites throughout the study. The hemipteran *Trichocorixa verticalis interiores* was the only insect observed in large numbers in saline waters.

A total of 37 rotifer species were identified, indicating an impoverished fauna of low diversity. This is not surprising, considering the extreme environmental parameters; only the samples taken from Lake Winnipegosis show a reasonably high diversity (20 spp.). However, rotifers were found in all categories of water sampled with 16 species in salt marshes, 11 in fresh waters, 8 in mesosaline salt springs and seeps and only 1 in the hypersaline salt spring category. At salt springs 15 and 16 rotifers were not found in the cauldrons but were present downstream. This was not unexpected, as low water temperatures in the cauldrons may restrict successful colonization. Flowing water or seepage areas devoid of nanoplankton algae, bacteria or organic detritus are unfavourable for rotifers.

While numerous samples were taken at six different times, many rotifer species were found but once, at only one or two sites, suggesting that these species were either strongly seasonal or that immigrants were unable to develop viable populations within the environmental parameters offered. Again, migrating birds are the most likely means by which rotifers were transported.

TABLE 18. Foraminifera and Arcellacean distribution relative to physico-chemical parameters.

Species	Filterable Residue TDS ‰	Salinity ‰	pH units	SO_4 mg/l	Na+K mg/l	Ca mg/l	Mg mg/l	Cl mg/l	HCO_3 mg/l
J. macrescens	7.5-56.6	6.2-54.2	7.15-8.4	460-2650	2007-19275	220-1030	112-270	3400-30000	139-364
J. macrescens (d)*	2.5-63.2	1.6-61.0	6.8-8.4	78-3493	602-21473	59-1347	19-423	861-33750	120-461
J. macrescens polystoma	50.8	51.1	8.1	2360	16915	1000	249	28300	209
J. macrescens polystoma (d)	7.5-50.8	6.2-51.1	7.4-8.4	500-3493	2007-16915	220-1347	112-423	3400-28300	163-290
M. fusca (d)	63.2	61.0	6.8	2940	21473	1203	257	33750	377
P. ipohalina	7.5	6.2	8.4	500	2007	220	112	3400	264
P. ipohalina (d)	7.5-56.6	6.2-54.2	7.15-8.4	460-2650	2007-19275	220-1030	112-206	3400-30000	139-461
A. viriosa	20.4	18.1	7.4	1940	6190	495	136	10000	163
C. aculeata (d)	3.3-63.2	4.0-61.0	6.8-8.1	165-2940	1478-21473	146-1203	47-270	2180-33750	143-377
C. constricta	3.3	4.0	7.75	165	1478	146	47	2180	185
C. constricta (d)	3.3-31.1	4.0-30.8	7.75-8.1	78-1500	1205-10140	130-587	47-132	2180-17040	143-438
C. tricuspis (d)	11.0-31.1	10.6-30.8	7.15-8.1	460-1693	3608-10140	308-668	127-206	5850-17010	143-364
D. corona (d)	49.1	41.7	7.55	3493	14603	1347	423	23100	290
D. globulus (d)	3.3-49.1	4.0-41.7	7.55-7.75	165-3493	1478-14603	146-1347	47-423	2180-23100	185-290
D. oblonga (d)	3.3-63.2	4.0-61.0	6.8-8.0	78-3493	1205-21473	130-1203	47-423	2180-33750	185-438
D. protaeiformis(d)	20.4	18.1	7.4	1940	6190	495	136	10000	163
H. sphagni (d)	3.3	4.0	7.75	165	1478	146	47	2180	185
P. compressa (d)	3.3	4.0	7.75	165	1478	146	47	2180	185

*(d) = dead

Table 19. Distribution of aquatic molluscs relative to filterable residue.

Site	13	4.3‰	TDS	*Stagnicola (Stagnicola) elodes* (Say)* (these were found in all stages of development)
	14	7.0‰	TDS	*Lymnaea stagnalis jugularis* (Say)*
				*Stagnicola elodes**
				Helisoma (Pierosoma) trivolvis subcrenatum (Carpenter)*
	9	3.3‰	TDS	*Oxyloma retusa* (Lea)*
				Fossaria modicella (Say)*
	15	34.3‰	TDS	*Valvata tricarinata* (Say)
				Gyraulus deflectus (Say)
				Pisidium (Cyclocalyx) compressum Prime
	5	9.1‰	TDS	*Stagnicola elodes**
	7	49.1‰	TDS	*Stagnicola elodes*
				Helisoma (Helisoma) anceps anceps (Menke)

*(includes live in addition to dead specimens)

Nielsen et al. (1987) documented the presence of *Cribroelphidium gunteri* a mid-Holocene foraminiferan in beach ridges near Lake Winnipegosis. A benthic sample taken in 1987 from Site 11 was found to contain *Jadammina macrescens* which is known to occur in coastal marshes worldwide (Scott and Martini 1982) including Hudson Bay and both the east and west coasts of North America. During the following year four foraminiferal species and nine arcellaceans were identified. Further study indicated that *J. macrescens* dominated the modern foraminiferal fauna and live specimens were found in fresh water, salt marshes and salt seeps. *Polysaccammina ipohalina* and *Miliammina fusca*, like *J. macrescens*, have been found previously in coastal marshes but have never been taken this distance inland (Scott and Martini 1982; Patterson et al. 1990).

Table 20. Birds observed at the study sites.

Waterbirds	
Black Tern	*Chlidonias niger* (Linnaeus)
Forster's Tern	*Sterna forsteri* Nuttall
Double-crested Cormorant	*Phalacrocorax auritus* (Lesson)
Northern Pintail	*Anas acuta* Linnaeus
Canvasback	*Aythya valisineria* (Wilson)
Canada Goose	*Branta canadensis* (Linnaeus)
Franklin's Gull	*Larus pipixcan* Wagler
Shorebirds	
Least Sandpiper	*Calidris minutilla* (Vieillot)
Semipalmated Plover	*Charadrius semipalmatus* Bonaparte
Piping Plover	*Charadrius melodus* Ord
Greater Yellowlegs	*Tringa melanoleuca* (Gmelin)
American Avocet	*Recurvirostra americana* Gmelin
Lesser Yellowlegs	*Tringa flavipes* (Gmelin)
Pectoral Sandpiper	*Calidris melanotos* (Vieillot)
Baird's Sandpiper	*Calidris bairdii* (Coues)
Semipalmated Sandpiper	*Calidris pusilla* (Linnaeus)
Marbled Godwit	*Limosa fedoa* (Linnaeus)

Patterson et al. (1985) consider arcellaceans to be fresh water animals intolerant of even low salinity levels. It is therefore probable that the arcellaceans were carried into the more saline habitats from nearby fresh waters during periods of high water or heavy rainfall as suggested by Patterson (1987), as most sites are downstream from fresh water marshes or in the flood zone of Lake Winnipegosis. Nevertheless, flooding cannot explain the presence of *Centropyxis aculeata* in Site 4 which is about 1 km from a fresh water pond. Avian transport is the most probable mechanism for both local and long distance dispersal of both the foraminifera and the arcellaceans.

Dead *Helisoma anceps anceps* and *Stagnicola elodes* had been taken earlier at Site 7 by Petch (1987). Here and at Site 15 only empty shells were recovered. Since both mesosaline sites border Lake Winnipegosis it is probable that these shells represent detrital drift, a view supported by the presence of sphaeriids commonly found in the lake at Site 15. Live fresh water molluscs were taken only in subsaline or hyposaline environments with TDS below 9.1 ‰. It is unlikely that freshwater species can tolerate significantly higher salinities, thereby precluding their presence in the more saline sites. Although birds are known to transport molluscs, the absence of marine species confirmed the difficulties associated with extensive migration from coastal area by macro-invertebrates.

In conclusion, the sodium chloride dominated waters studied have a common source although salinity is altered both by dilution and by the source of the diluting waters. Biologically, the widespread distribution of dead shelled species together with the sporadic distribution of living species and the overall relatively low species diversity suggests that continued random colonization is coupled with low immigrant viability. In the past these environments may have offered certain immigrants greater opportunity for survival but as these environments changed over time various species could not adapt to more hostile conditions and simply died out. Although many species have populations that apparently persist for

years, immigration is likely a contributing and probably a necessary factor for the continuity of at least some species. While Lake Winnipegosis and the sulphate dominated lakes in Saskatchewan harbour many of the species found in this study, some were previously known only from coastal marine marshes. This indicates that immigration is not simply a local phenomenon and that long distance transport is involved. The two new species may represent unknown oceanics, but it is equally likely that they have evolved in response to environmental selection pressures within their individual isolated habitats as they have not been found elsewhere. They may have very specific requirements or may not be readily transported, or their rapid evolution may have precluded their dispersal.

Acknowledgments

We thank the Manitoba Museum of Man and Nature Foundation and The Manitoba Heritage Federation Inc. for grants to W.B.M. and NSERC for grant OGP0041665 to R.T.P. in support of this research. Thanks are due also to the W. M. Ward Technical Services Laboratory and Atomic Energy of Canada, Pinawa for the water analyses. R. Betcher of Water Resources Branch, Manitoba Natural Resources, interpreted the stable isotope data and provided much valuable insight into the water chemistry. G. Jones aided W.B.M. in the field and provided the vegetation and salinity data for Table 1. G. Bird, H. Copland, J. Dubois, M. McKillop, W. Neally and M. Stephenson assisted in the field. V. Petch provided background information on some sites. We thank the three anonymous reviewers for helpful comments on the manuscript. Special thanks are due to E. Nielsen and D. Scott for their encouragement throughout the project.

Literature and Documents Cited

Entries marked * after the date are unpublished documents.

Ahlstrom, E. H. 1940. A revision of the Rotatorian genera *Brachionus* and *Platyias* with the description of one new species and two new varieties. Bulletin of the American Museum of Natural History 77: 143–184.

Anonymous. 1980. Analytical Methods Manual. Technical Services Laboratory, Winnipeg, Manitoba. Unpaginated.

Barica, J. 1975. Geochemistry and nutrient regime of saline eutrophic lakes in the Erickson-Elphinstone district of southwestern Manitoba. Fisheries and Marine Service. Freshwater Institute, Winnipeg. Technical Report 511. 82 pages.

Cameron, E. L. 1949. Salt, potash and phosphate in Manitoba. Department of Mines and Natural Resources. Mines Branch. Bulletin 48–9. 13 pages.

Champagne, D. E., C. R. Harington and **D. E. McAllister.** 1979. Deepwater sculpin, *Myoxocephalus thompsoni* (Girard) from a Pleistocene nodule, Green Creek, Ontario, Canada. Canadian Journal of Earth Sciences 16: 1621–1628.

Chengalath, R. and **W. Koste.** 1987. Rotifera from Northwest Canada. Hydrobiologia 147: 49–56.

Cole, L. H. 1915. Report on the salt deposits of Canada and the salt industry. Number 325, Pages 49-73, Chapter V. Canada Department of Mines, Ottawa.

Day, M. J. 1977. Analysis of movement and hydrochemistry of groundwater in the fractured clay and till deposits of the Winnipeg area, Manitoba. M.Sc. thesis, University of Waterloo, Waterloo, Ontario. 210 pages.

Delorme, L. D. 1965. Pleistocene and post-pleistocene ostracods of Saskatchewan. Ph.D. thesis, University of Saskatchewan, Saskatoon, Saskatchewan. 245 pages.

Delorme, L. D. 1970. Freshwater ostracodes of Canada. Part I. Subfamily Cyridinae. Canadian Journal of Zoology 48: 153–168.

Delorme, L. D. 1971a. Freshwater ostracodes of Canada. Part V. Families Limnocytheridae, Loxoconchidae. Canadian Journal of Zoology 49: 43–64.

Delorme, L. D. 1971b. Paleoecological determinations using Pleistocene freshwater ostracodes. Centre de Recherche Pau-SNPA. Bulletin, Volume 5, Supplement, pages 341–347.

Delorme, L. D. 1973*. Freshwater Ostracoda from Lake Manitoba, Part I. Water Resources Branch, Unpublished Service Report, Burlington, Ontario (73-85). 39 pages.

Delorme, L. D. 1974a*. Freshwater Ostracoda from Lake Manitoba, Part II. Water Resources Branch, Unpublished Service Report, Burlington, Ontario (74-O-92). 30 pages.

Delorme, L. D. 1974b*. Freshwater Ostracoda from Lake Manitoba, Part III. Water Resources Branch, Unpublished Service Report, Burlington, Ontario (74-O-106). 10 pages.

Delorme, L. D. 1977*. Freshwater Ostracoda from Manitoba. Water Resources Branch, Unpublished Manuscript, Burlington, Ontario. 121 pages.

Delorme, L. D. 1984. Limnological data for Big Quill Lake, Fife Lake, Last Mountain Lake, Lake Lenore, Little Manitou Lake, Little Quill Lake, Old Wives Lake and Waldsea Lake in Saskatchewan as well as ostracodes and molluscs from these lakes. Report Number 84-0-193. National Water Research Institute. Water Resources Branch, Burlington, Ontario. 38 pages.

Forester, R. M. 1983. Relationship of two lacustrine ostracode species to solute composition and salinity: Implications for paleohydrochemistry. Geology 11: 435–438.

Hammer, U. T. 1986. Saline lake ecosystems of the world. Monographiae Biologicae. Volume 59. *Series Editor* H. J. Dumont. Junk 28, Publishers. The Netherlands. 616 pages.

Hem, J. D. 1959. Study and interpretation of the chemical characteristics of natural water. Geological Survey Water-supply Paper 1473. U.S. Department of the Interior. 269 pages.

Hind, H. Y. 1971. Narrative of the Canadian Red River Exploring Expedition of 1857 and of the Assiniboine and Saskatchewan Exploring Expeditions of 1858. Hurtig Publishers. Edmonton. Volume II. 472 pages.

Hitchon, B. 1969. Fluid flow in the western Canada sedimentary basin. I. Effect of topography. Water Resources Research 5: 186–195.

Hitchon, B., G. K. Billings and **J. E. Klovan.** 1971. Geochemistry and origin of formation waters in the western Canada sedimentary basin. III. Factors control-

ling chemical composition. Geochimica et Cosmochimica Acta. 35: 567–598.

Hitchon, B., A. A. Levinson and **S. W. Reeder.** 1969. Regional variations of river water composition resulting from halite solution, MacKenzie River drainage basin, Canada. Water Resources Research 5: 1395–1403.

Jones, G. 1991. Competitive processes and spacial patterning of plant species in inland boreal saline habitats. M.Sc. thesis, University of Manitoba, Winnipeg, Manitoba. 276 pages.

Lerman, A. 1978. Lakes. Chemistry, Geology, Physics. Springer-Verlag. New York. 363 pages.

McCabe, H. R. and **D. Barchyn.** 1982. Paleozoic stratigraphy of Southwestern Manitoba. Field Trip 10. Geological Association of Canada. 47 pages.

Moore, J. E. 1952. The Entomostraca of southern Saskatchewan. Canadian Journal of Zoology 30: 410–449.

Neale, J. W. and **L. D. Delorme.** 1985. *Cytheromorpha fuscata*, a relict Holocene marine ostracod from freshwater inland lakes of Manitoba, Canada. Revista Espanola de Micropaleontologia 17(10): 41–64.

Nielsen, E., D. H. McNeil and **W. B. McKillop.** 1987. Origin and paleoecology of post-Lake Agassiz raised beaches in Manitoba. Canadian Journal of Earth Sciences 24: 1478–1485.

Patterson, R. T. 1987. Arcellaceans and foraminifera from Pleistocene Lake Tecopa, California. Journal of Foraminiferal Research 17: 333–343.

Patterson, R. T., K. D. MacKinnon, D. B. Scott and **F. S. Medioli.** 1985. Arcellaceans ("Thecamoebians") in small lakes of New Brunswick and Nova Scotia: Modern distribution and Holocene stratigraphic changes. Journal of Foraminiferal Research 15: 114–137.

Patterson, R. T. and **W. B. McKillop.** 1991. Distribution and possible paleoecological significance of *Annectina viriosa*, a new species of agglutinated foraminifera from nonmarine salt ponds in Manitoba. Journal of Paleontology 65: 33–37.

Patterson, R. T., D. B. Scott and **W.B. McKillop.** 1990. Recent marsh-type agglutinated foraminifera from Inland Salt Springs, Manitoba, Canada. Pages 765-781 *in* Paleoecology, Biostratigraphy, Paleoceanography and Taxonomy of Agglutinated Foraminifera. *Edited by* C. Hemleben, M. Kaminsky, W. Kuhnts and D. B. Scott Kluwer Academic Publishers, Netherlands.

Petch, V. 1987. The 1986 survey of salt flats and pools along the western shore of Lake Winnipegosis. Manitoba Archaeological Quarterly 11: 13–22.

Scott, D. B. and **I. P. Martini.** 1982. Marsh foraminifera zonations in western James and Hudson bays. Le Naturaliste Canadien 109: 399–414

Scott, D. B. and **F. S. Medioli.** 1980. Quantitative studies of marsh foraminiferal distributions in Nova Scotia. Implications to sea level studies. Cushman Foundation For Foraminiferal Research. Special Publication Number 17. 58 pages.

Simpson, F., H. R. McCabe and **D. Barchyn.** 1987. Subsurface disposal of wastes in Manitoba. Part 1. Manitoba Energy and Mines. Geological Paper GP 83-1. 47 pages.

Stephenson, J. F. 1973. Geochemical Studies: Summary of Geological Field Work. Department of Mines, Resources and Environmental Management, Manitoba, Geological paper 2/73: 7–8.

Tones, P. I. and **U. T. Hammer.** 1975. Osmoregulation in *Trichocorixa verticalis interiores* Sailer (Hemiptera, Corixidae) — an inhabitant of Saskatchewan saline lakes, Canada. Canadian Journal of Zoology 53: 1207–1212.

Tyrrell, J. B. 1892. Report on north-western Manitoba. Annual Report, Volume V. Part I. 1891. Geological Survey of Canada. 235 pages.

van Everdingen, R. O. 1971. Surface-water composition in southern Manitoba reflecting discharge of saline subsurface waters and subsurface solution of evaporites. Geological Association of Canada, Special Paper 9, pages 343–352.

Wadien, R. 1984*. The geochemistry and hydrogeology of saline spring waters of the Winnipegosis area, southwestern Manitoba. Unpublished B.Sc. Thesis. University of Manitoba, Winnipeg, Manitoba. 63 pages.

Received 27 January 1992
Accepted 18 April 1993

Nest Sites and Habitat Selected by Cooper's Hawks, *Accipiter cooperii,* in Northern New Jersey and Southeastern New York

THOMAS BOSAKOWSKI,[1] DWIGHT G. SMITH,[2] AND ROBERT SPEISER[3]

[1]Department of Biological Sciences, Rutgers University, Newark, New Jersey 07102
Present address: Utah Division of Wildlife Resources, Fisheries Experiment Station, 1465W 950N, Logan, Utah 84321)
[2]Biology Department, Southern Connecticut State University, New Haven, Connecticut 06515
[3]13 Beam Place, Haledon, New Jersey 07508

Bosakowski, Thomas, Dwight G. Smith, and Robert Speiser. 1992. Nest sites and habitat selected by Cooper's Hawks, *Accipiter cooperii,* in northern New Jersey and southeastern New York. Canadian Field-Naturalist 106(4): 474–479.

Twenty-one Cooper's Hawk (*Accipiter cooperii*) nests were located in an extensively forested region of the northeastern United States. Nesting occurred mostly in mixed deciduous-coniferous forest with Eastern Hemlock (*Tsuga canadensis*) the dominant coniferous species in many nest sites. Nest sites had significantly greater percentages of coniferous trees (34.6%) than random sites (8.2%). Nest site stands also possessed a larger basal area and more canopy cover than random sites. All nests were constructed in live overstory trees (42.9% conifers), typically within the forest canopy. Nest trees were often (42.9%) the largest tree in the nest site. Although nest sites were always in heavily forested areas (87% forest cover), they were significantly closer to forest openings and wetlands (which often provided openings) than random sites. Nest sites were frequently on level ground or on lower slopes, never on ridgetops or steep upper slopes. Slope aspects differed from random sites, the southern quadrat was avoided for nesting. Nest sites were not significantly further from paved roads than random sites. Five nests were located within 37-100 m of paved roads suggesting that nesting Cooper's Hawks can be remarkably tolerant to car traffic and require only a very short buffer distance. However, most nests occurred in deeper forests since distance to paved roads and human habitation averaged 511m and 687m, respectively.

Key Words: Cooper's Hawk, *Accipiter cooperii*, macrohabitat, microhabitat, nest sites.

The Cooper's Hawk (*Accipiter cooperii*) is a secretive forest hawk of North America. Aspects of its nesting ecology have been studied in New York (Meng 1951), Massachusetts (Bent 1937), Maryland (Titus and Mosher 1981), Michigan (Craighead and Craighead 1956), Oregon (Reynolds et al. 1978, 1982; Moore and Henny 1983, 1984), New Mexico (Kennedy 1988), Utah (Fischer 1986), and California (Asay 1987). However, few studies have made a quantitative assessment of nesting habitat. Reynolds et al. (1982), Moore and Henny (1983), Fischer (1986), and Kennedy (1988) studied nesting habitat in western North America, and Rosenfield and Anderson (1983) provided data from nest sites in the Mid-West (Wisconsin). However, in eastern North America, information on nest site habitat is limited to anecdotal accounts in Bent (1937) and Meng (1951) and data from six nest sites in Maryland (Titus and Mosher 1981).

In this paper, we present a quantitative description of habitat selection based on 21 nest sites from an extensively forested region in the Northeast. These results may help elucidate the critical habitat requirements of nesting Cooper's Hawks within the Eastern Deciduous Forest Biome.

Study Area

The study was conducted in the Highlands of northern New Jersey (Passaic, Morris, and Sussex counties) and southeastern New York (Orange County). This region is characterized by rolling, granitic hills and is part of the Reading Prong, a southerly extension of the New England Uplands. The region is extensively forested and sparsely populated, especially in the north and central sections. The dominant direction of relief lies southwest to northeast and elevations vary from 507 m to nearly sea level.

The study area lies in the central oak-hardwood region, but is ecotonal in character, having a climax forest of northern hardwoods (Robichaud and Buell 1973). Although oaks (*Quercus* spp.) predominate in most areas, coniferous growth often occurs in areas of cool, moist microclimate such as in lowlands, valleys, ravines and along water courses. Eastern Hemlock (*Tsuga canadensis*) is the dominant conifer followed by White Pine (*Pinus strobus*). Mature conifer plantations of White Pine, Red Pine (*P. resinosa*), Scotch Pine (*P. sylvestris*), and Norway Spruce (*Picea abies*) are distributed sporadically throughout the area, especially in watersheds. Natural forests are a mosaic of young and mature stands; old-growth is rare. A more detailed description of this region is presented elsewhere (Speiser and Bosakowski 1987).

Methods

We located 21 Cooper's Hawks nests from 1983 to 1990. Ten nests were found by searching wood-

lands on foot during the course of general raptor nesting surveys (Speiser and Bosakowski 1987, 1988; Bosakowski et al. 1989a,b) and breeding bird surveys (Benzinger et al. 1988) in the Highlands. Nine nests were found during a systematic broadcast survey of all known forest raptors (Bosakowski 1990). Two nests were discovered while driving through study areas during regular field work sessions. Since a diversity of species was under investigation during these surveys, no specific search image or bias for Cooper's Hawk habitat was involved in locating nests. Most nests were located in March and April, prior to leaf-out, and were then rechecked at least once for occupancy in May or June. Nests found after leaf-out were generally aided by protesting Cooper's Hawks in response to various broadcasted raptor calls or human intrusion.

Mosher et al. (1986) suggested that raptor habitat studies should contain variables that can be readily obtained by forest managers. Therefore, we estimated tree basal area of nest site stands by standard "timber cruising" methods using a 10-factor angle gauge (English scale). Basal area samples were estimated at nest sites with five point-sampling tree tallies which were systematically established at each nest site, including one at the nest tree, and one in each of the four cardinal directions, 50 m from the nest tree. Along each 50 m cardinal axis, five stops were made at 10 m intervals to note the presence or absence of canopy cover and shrub/sapling cover. Canopy cover presence was obtained using an ocular sighting tube (James and Shugart 1970). Shrub/sapling cover was considered present if within arms reach (Collins et al. 1982) of vegetation greater than 0.5 m in height, but less than 10 cm in DBH. Shrubs and saplings were pooled together (after Collins et al. 1982) since they are structurally similar. Percent of coniferous trees was calculated from basal area tree tallies. These methods were also used to characterize 24 random sites which were selected by random coordinates using a random numbers table. In the field, to avoid bias in determining the exact center of the plots, we walked an additional 50 paces in a random cardinal compass direction as dictated by a series of coin flips.

At each nest site, we recorded the nest tree species, number of nest support branches, and condition of the nest tree (live, dead, or diseased). Diameter of the nest tree at breast height (DBH) was calculated from circumference measurements made with a measuring tape. Height of the nest and nest tree were measured with a triangulation instrument constructed with a sighting tube, protractor, and line level mounted on a locking tripod. Baseline from the nest tree to the instrument was measured with a steel measuring tape.

Eight macrohabitat variables were measured for 21 nest sites using standard 7.5 min USGS quadrangle maps. Data were also obtained for 70 computer-generated random sites which were taken from a previous study conducted in the same study area (Speiser and Bosakowski 1988). Distances of nest sites and random sites to the nearest paved road, forest opening (non-forested area >1 ha), wetland (>0.5 ha), lake/pond, stream, and human habitation were measured from maps. Slope was figured over a 300 m baseline through the nest tree or random site. Slope aspect was figured only for sites with at least two percent slope. Slope location was qualitatively ranked into one of four categories only when slopes were longer than 180 m: 0 = no slope, 1 = lower slope, 2 = middle slope, 3 = upper slope. Elevations were taken from the quadrangle maps.

Nest site and random site data were compared statistically using a non-parametric rank test (Mann-Whitney U-test), therefore, non-normal, percentage, and rank scores did not need data transformations prior to analysis (Zar 1974). All statistical tests were run on RS/1 software (Bolt, Baranek, and Newman, Cambridge, Massachusetts). Slope aspects were compared using a chi-squared test. Vegetation variables of nest sites were compared to mean values in the literature by use of the t-statistic (Zar 1974) calculated from our data.

Results and Discussion

From 1983 to 1990, 21 Cooper's Hawk nest sites were located in the study area. At least seven of the nests had several old nests nearby (<150 m), but only the most recent active nest was used for this study. We did not include any data from previous alternate nests because of pseudoreplication (Mosher et al. 1987), i.e., most of the habitat variables would tend to show similar values and would cause overweighting bias of these factors. The 21 nest sites were widely separated, and thus probably were occupied by different pairs. The closest nearest neighbor distance found during the same year was 1.2 km which was similar to the 1.3 km minimum internest distance reported for Cooper's Hawks in Wisconsin (Rosenfield and Anderson 1983).

Nest Tree Characteristics

Cooper's Hawks nested only in live trees, with a nearly equal use of deciduous and coniferous tree species. Nests were in 4 White Pine; 2 Eastern Hemlock, 2 Scotch Pine; 2 American Beech (*Fagus grandifolia*), 2 Black Birch (*Betula lenta*), 2 White Oak (*Quercus alba*), 2 Red Oak (*Q. rubra*), 1 Sugar Maple (*Acer saccharum*), 1 Red Maple (*A. rubrum*), 1 Chestnut Oak (*Q. prinus*), 1 Black Gum (*Nyssa sylvatica*), and 1 Norway Spruce. Nests in Scotch Pine and Norway Spruce (non-native species) have not been reported previously. White Pine was the most common nesting tree in Wisconsin (35.4%; Rosenfield and Anderson 1983), Massachusetts

TABLE 1. Nest tree and stand characteristics of Cooper's Hawk in northern New Jersey and southeastern New York and comparison to the literature with t-statistic based on standard deviation (± SD) reported in this study.

Study Area	Nest Tree					Nest Stand		
	Nest Ht		Height	%Nest	DBH		Basal	%Canopy
	n	(m)	(m)	Height	(cm)	*n*	(m^2/ha)	Cover
New Jersey-	21	16.7	25.0	67.3	44.0	21	30.9	88.9
New York (this study)		±3.1	±4.2	±8.8	±12.6		±7.8	±6.5
Literature Mean Values (see below for numbered sources)								
1 Maryland	6	15.4	ND	67.5	44.5	6	24.3	76.0*
2 Wisconsin	60	12.8*	20.4*	63.7	33.2*	60	ND	82.8
3 NE Oregon	31	12.1*	ND	ND	43.7	31	39.5*	ND
4 NW Oregon	18	15.2*	22.3*	ND	33.2*	4	30.7	75.0*
5 E Oregon	15	14.0*	22.6*	ND	39.6	5	41.3*	64.0*
6 New Mexico	12	16.1	24.1	ND	52.1*	12	17.0	ND
7 Utah	17	7.1*	12.2*	ND	17.6*	17	ND	83.1

*$p < 0.05$ t-test, 2-tailed, ND = no data available.
1 - Titus and Mosher (1981), 2 - Rosenfield and Anderson (1983),
3 - Moore and Henny (1983), 4, 5 - Reynolds et al. (1982), 6 - Kennedy (1988), 7 - Fischer (1986).

(58.3%; Bent 1937) and this study (19.0%). In this study, nest height was significantly higher (18.0 m) in conifers than in deciduous trees (15.3 m)(*t*-test, 2-tailed, $p = 0.046$).

Nests were built in primary crotches (42.1%), secondary crotches (15.8%), at the base of limb axils (31.6%), and out on limb forks away from the main trunk (10.5%). The average number of support branches was 4.2 with a range of 2 to 6. Two nests were also connected with neighboring tree trunks (same species) which may have aided in additional support and concealment.

All Cooper's Hawk nests were in large overstory trees and were frequently in the largest tree in the nest site plots (9 of 21 nest sites, 42.9%). The mean nest tree DBH in our study averaged 44.0 cm and was relatively large compared to other North American study areas (Table 1). In addition to large DBH, mean nest tree height and nest height of Cooper's Hawks in this study were significantly higher than most other North American study sites (Table 1). The concurrent preference for large diameter nest trees in our study area was not simply a result of a correlation with nest tree height ($r = 0.28$, $p = 0.22$). Thus, tree height and girth both appear to offer important cues for nest tree selection.

Overall, these results indicate that Cooper's Hawks in eastern North America generally select larger nest trees than in western study areas. One reason could be that eastern Cooper's Hawks are 23% larger in body weight than their western counterparts (Smith et al. 1990). We also suggest that in areas with a higher deciduous component, Cooper's Hawks are more apt to conceal their nests higher up in the canopy where most of the foliage is available for concealment.

Microhabitat Selection

Nest site locations ranged from nearly pure coniferous stands to nearly pure deciduous, but most had mixed forest (mean 34.6% conifer density). Only two nest sites (10.5%) were in pure deciduous stands. Typically, stands of hemlock and/or pine were conspicuously associated with nest sites and conifers were found significantly less at random sites (Table 2). The reason for preference of conifers is not known, but probably relates to nest concealment, nest microclimate, and/or prey base. Conifers usually formed a dominant component of the Cooper's Hawk habitat in northwestern North America (Reynolds et al. 1982; Moore and Henny 1983), but not in the southern intermountain areas of the Rocky Mountains (Fischer 1986; Kennedy 1988) or the central Appalachians (Titus and Mosher 1981). However, six of seven Cooper's Hawk nests in Ohio study areas were in groves of pines planted in the 1930s, although pine groves covered less than 1% of the areas surveyed (Mutter et al. 1984).

In this study, Cooper's Hawks showed a preference for more mature forests than the average habitat available, exemplified by larger basal areas at nest sites than at random sites (Table 2). The avoidance of young stands for nest sites has not been tested in most studies, but probably relates to the lack of tall trees for nesting or reduced ability of Cooper's Hawks to forage in young forest with very high stem densities. Basal area of the nest site stand in our study was comparable to most other study areas except eastern and northeastern Oregon study areas (Table 1) where average tree size is expected to be larger.

Canopy cover was significantly greater at nest sites than at random sites (Table 2). Although other study areas averaged slightly less canopy cover (64.0-83.1%), it is evident that dense canopy cover is

TABLE 2. Habitat characteristics at Cooper's Hawk nest sites and random sites. Values are means ± SD with range in parentheses. Probability levels are the results of 2-tailed Mann-Whitney U-tests.

	Nest Sites	Random Sites	P-value
Microhabitat	n = 21	n = 24	
Basal Area (m^2/ha)	30.9 ± 7.82 (16.2 - 45.9)	23.7 ±4.83 (12.6 - 37.4)	0.0006
Conifer Density (%)	34.6 ± 23.3 (0 - 76.6)	8.2 ± 17.2 (0 - 80.7)	0.0001
Canopy Cover (%)	88.9 ± 6.51 (80 - 100)	82.5 ± 8.76 (65 - 100)	0.0151
Shrub/Sapling Cover (%)	59.3 ± 23.8	69.0 ± 27.5 (10 - 95)	0.1571 (5 - 100)
Macrohabitat	n = 21	n = 70	
Distance Opening (m)	120.1 ± 78.7 (18 - 600)	238.1 ± 210.0 (0 - 850)	0.0449
Distance Paved Road (m)	511.0 ± 488.0 (3 - 1760)	501.9 ± 452.7 (0 - 2600)	0.9324
Distance Wetland (m)	307.1 ± 375.9 (30 - 1600)	564.8 ± 541.07 (0 - 2600)	0.0243
Distance Water (m)	191.1 ± 151.5 (30 - 720)	250.8 ± 210.88 (10 - 900)	0.3509
Distance Human Habitation (m)	687.9 ± 585.8 (185 - 2200)	730.1 ± 516.46 (50 - 2360)	0.4151
Slope (%)	6.0 ±6.09 (0 - 20)	8.7 ± 5.84 (0 - 28)	0.0772
Slope Location (0-3)	0.57 ± 0.68 (0 - 2)	1.14 ± 1.12 (0 - 3)	0.0519
Elevation (m)	305.7 ± 59.8 (195 - 393)	273.1 ± 84.16 (70 - 420)	0.1281

an important requirement for nesting Cooper's Hawks in all regions (Table 1), affording greater protection from weather extremes and predators. Reynolds et al. (1982) suggested that *Accipiter* may have low tolerances for direct sunlight and nests are rarely built in isolated trees (Asay 1987). Despite consistency in canopy cover at nest sites in this study (CV = 7.3%), shrub/sapling cover varied considerably (CV = 40.1%) and showed a low inverse correlation with canopy cover (r = -0.235). Sites in younger stands and/or more xeric terrain often had a heavy understory of mountain laurel (*Kalmia latifolia*) and various saplings. Overall, Cooper's Hawk nest sites usually had a dense shrub/sapling cover (mean 59.3%) which was not different than random sites despite larger tree basal areas.

Macrohabitat Selection

Cooper's Hawk nests were not significantly closer or further to human habitation and paved roads than random sites. Five nests were found relatively close (110-200m) to houses which was probably attributable to their secretive nesting behavior and infrequent nest-defense behavior toward human intruders (e.g., only 2 of 21 pairs conspicuously defended their nest against field workers on the gound). Bent (1937:120) also stated that nesting Cooper's Hawks were usually shy, flying swiftly away, and generally not returning to protest. Such habits probably allow nesting close to residential areas, an researchers should be careful not to exclude these habitats during surveys or habitat management priorities.

The usual tendency to nest away from paved roads can not be explained simply as an avoidance of vehicle traffic and human disturbance (Hennessy 1978) since five of 21 nests in this study were located within 37-100 m of paved roads. These results demostrate that nesting Cooper's Hawks can be remarkably tolerant to car traffic and require only a very short buffer distance. Overall, most nests were far from roads (mean = 511m) and human habitation (mean = 687m) may which reflect a preference for relatively large tracts of undeveloped forest which are required to sustain many populations of interior forest-nesting bird species (Galli et al. 1976; Lovejoy et al. 1986; Robbins et al. 1989). The food requirements of nesting Cooper's Hawks may not be sufficiently met in small fragmented forest tracts and dense suburban areas.

The mean distance to forest openings was significantly closer for nest sites than for random (Table 2),

and 13 nests (61.9%) were within 150 m of large openings (>1 ha). However, we analyzed a subset of 12 nests from aerial photographs which revealed an average of 87% forest cover within a 300 m radius of nests (Bosakowski et al. 1993) suggesting that nesting occurred in habitat that was extensively forested. In the Mid-West, forest openings averaged closer (66 m) at Cooper's Hawk nest sites in Wisconsin (Rosenfield and Anderson 1983) and Meng (1951) also reported that nests were near forest edges or other openings in New York state. Since Cooper's Hawks are primarily bird-feeding raptors in our study region (Bosakowski 1990), an association with forest openings may provide higher prey densities (prey density hypothesis) and/or easier prey capture (prey vulnerability hypothesis)(Craighead and Craighead 1956).

Cooper's Hawk nests occurred significantly closer to wetlands than random sites. Since nearly all wetlands contained sizable non-forested areas, it is likely that close wetland proximity was favored due to the open and edge habitats available for hunting.

Nest sites showed no significant difference in proximity of water sources (lakes, ponds, streams). However, this may reflect the general abundance and availability of water in the study area and may not be a usable discriminating factor in nest site selection in this region. Reynolds et al. (1982) considered nearby water to be an important component of most Cooper's Hawk nest sites, although Rosenfield and Anderson (1983) generally found nests considerably farther from water (mean = 497 m).

Cooper's Hawks nested on flatter terrain and on lower portions of slopes compared to random sites and no nest sites occurred on upper slopes (rank = 3). This preference may be correlated with taller tree growth and greater abundance of conifers in valley bottoms, lowlands, and along water courses as well as with wetland proximity. Cooper's Hawks in Wisconsin also nested at relatively flat sites (mean = 3.2%) but less so in coniferous regions of Oregon (means = 16 to 18%) where terrain is typically more mountainous (Reynolds et al. 1982). No elevational difference between nest sites and random sites was found in our study area.

The slope aspects of nest sites were variable, but the southern quadrat (S, SW, SE) was avoided. An overall Chi-square test could not be performed because of zero values, but when we pooled values for the three southern aspects (S, SW, SE) against the remaining five aspects, nest sites were significantly different than random sites (Fisher Exact Test, 2-tailed, $p = 0.03$). Reynolds et al. (1982) also noted an avoidance of the southern quadrat for most Cooper's Hawk nests, probably because of the effect of greater solar radiation in lowering soil moisture, tree densities and shading. In our study area, we also noted a greater deciduous tree composition on slopes with southern exposures, perhaps making these aspects less desirable for nesting.

Reynolds (1983) hypothesized that accipiters probably select habitat based on the overall structural characteristics of a stand and then focus on a particular tree for nest building. Our results with Cooper's Hawks suggest a high selectivity of suitable macrohabitat features which possibly precedes attempts to find a suitable nesting stand (microhabitat). Thus, potential breeding habitat for Cooper's Hawks can be rapidly and accurately identified from topographic maps and aerial photographs, provided with a criteria that the areas under consideration are extensively forested and contain some coniferous component. Mapping results could then be used in developing a habitat management strategy which could help protect existing habitat and allow for successful mitigation attempts by relocating development and timber harvesting sites to less suitable nesting habitat.

Acknowledgments

Part of this study was from a doctoral research project of the senior author who was awarded research grants from the New Jersey Department of Environmental Protection - Endangered and Nongame Species Program and the New Jersey Audubon Society. We also would like to thank John Benzinger for assisting on nest searches and Thomas Koeppel of the Newark Watershed Office for allowing use of the aerial photographs.

Literature Cited

Asay, C. E. 1987. Habitat and productivity of Cooper's Hawks nesting in California. California Fish and Game 73: 80–87.

Bent, A. C. 1937. Life Histories of North American birds of prey.Part 1. United States National Museum Bulletin 167. Washington, D.C.

Benzinger, J., P. Bacinski, D. Miranda, and **T. Bosakowski.** 1988. Breeding birds of the Pequannock Watershed, 1986-87. Records of New Jersey Birds 14: 22–27.

Bosakowski, T. 1990. Community structure, niche overlap, and conservation ecology of temperate forest raptors during the breeding season. Ph.D. thesis, Rutgers University, Newark, New Jersey.

Bosakowski, T., J. Benzinger, and **R. Speiser.** 1989a. Forest owl populations of the Pequannock Watershed. Records of New Jersey Birds 15: 2–8.

Bosakowski, T., R. Speiser, and **D.G Smith.** 1989b. Nesting ecology of forest-dwelling Great Horned Owls in the Eastern Deciduous Forest Biome. Canadian Field-Naturalist 103: 65–69.

Bosakowski, T., R. Speiser, D.G Smith, and **L.J. Niles.** 1993. Loss of Cooper's Hawk nesting habitat to suburban development: inadequate protection for a state-endangered species. Journal of Raptor Research 27: 26–30.

Collins, S. L., F. C. James, and **P. G. Risser.** 1982. Habitat relationships of wood warblers (Parulidae) in northern central Minnesota. Oikos 39: 50–58.

Craighead, J. J. and **F. C. Craighead, Jr.** 1956. Hawks, owls and wildlife. Stackpole Publishing Co., Harrisburg, Pennsylvania.

Fischer, D. L. 1986. Daily activity patterns and habitat use of coexisting Accipiter hawks in Utah. Ph.D. thesis., Brigham Young University, Provo, Utah.

Galli, A., C. F. Leck, and **R. T. Forman.** 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93: 356–364.

Hennessy, S. P. 1978. Ecological relationships of Accipiters in northern Utah - with special emphasis on the effects of human disturbance. M.S. thesis, Utah State University, Logan.

James, F. C. and **H. H. Shugart, Jr.** 1970. A quantitative method of habitat description. Audubon Field Notes 24: 727–736.

Kennedy, P. L. 1988. Habitat characteristics of Cooper's Hawks and Northern Goshawks nesting in New Mexico. pages 218-227 *in*: Proceedings of the Southwest Raptor Management Symposium and Workshop, National Wildlife Federation, Washington, D.C.

Lovejoy, T. E., R. O. Bierregaard, Jr., A. B. Rylands, J. R. Malcolm, C. E. Quintela, L. H. Harper, K. S. Brown, Jr., A. H. Powell, G. V. N. Powell, H. O. R. Schubart, and **M. B. Hays.** 1986. Edge and other effects of isolation on Amazon forest fragments. pages 257-285 *in*: Conservation Biology: The Science of Scarcity and Diversity. *Edited by* M. E. Soule. Sinauer Associates, Sunderland, Massachusetts.

Meng, H. K. 1951. The Cooper's Hawk *Accipiter cooperii* (Bonaparte). Ph.D. thesis. Cornell University, Ithaca, New York.

Moore, K. R., and **C. J. Henny.** 1983. Nest site characteristics of three coexisting Accipiter hawks in northeastern Oregon. Raptor Research 17: 65–76.

Moore, K. R. and **C. J. Henny.** 1984. Age specific productivity and nest site characteristics of Cooper's Hawks (*Accipiter cooperii*). Northwest Science 58: 290–299.

Mosher, J. A., K. Titus, and **M. R. Fuller.** 1986. Developing a practical model to predict nesting habitat of woodland hawks. Pages 31-35 *in*: Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates. *Edited by* J. Verner, M. L. Morrison, C.J. Ralph, University of Wisconsin Press, Madison.

Mosher, J. A., K. Titus, and **M. R. Fuller.** 1987. Habitat sampling, measurement and evaluation. Pages 81-97 *in* Raptor Management Techniques Manual *Edited by* B. A. Millsap and K. W. Kline. National Wildlife Federation, Washington, D. C., Scientific and Technical Series, Number 10.

Mutter, D., D. Nolin, and **A. Shartle.** 1984. Raptor populations on selected park reserves in Montgomery County, Ohio. Ohio Academy of Science 84: 29–42.

Reynolds, R. J. 1983. Management of western coniferous forest habitat for nesting Accipiter hawks. USDA Forest Service General Technical Report RM-102. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Reynolds, R. J., and **H. M. Wight.** 1978. Distribution, density, and productivity of Accipiter hawks breeding in Oregon. Wilson Bulletin 90: 182–186.

Reynolds, R. J., E. C. Meslow, and **H. M. Wight.** 1982. Nesting habitat of coexisting Accipiter in Oregon. Journal of Wildlife Management 46: 124–138.

Robichaud, B., and **M. F. Buell.** 1973. Vegetation of New Jersey: A study of landscape diversity. Rutgers University Press, New Brunswick, New Jersey.

Robbins, C. S., D. K. Dawson, and **B. A. Dowell.** 1989. Habitat area requirements of breeding forest birds of the Middle Atlantic States. Wildlife Monographs 103: 1–33.

Rosenfield, R. N., and **R. K. Anderson.** 1983. Status of the Cooper's Hawk. Wisconsin Department of Natural Resources Project No. E-1-5, Madison, Wisconsin.

Smith, J. P., S. W. Hoffman, and **J. A. Gessaman.** 1990. Regional size differences among fall-migrant Accipiters in North America. Journal of Field Ornithology 61: 192–200.

Speiser, R., and **T. Bosakowski.** 1987. Nest site selection by Northern Goshawks in northern New Jersey and southeastern New York. Condor 89: 387–394.

Speiser, R., and **T. Bosakowski.** 1988. Nest site preferences of Red-tailed Hawks in the Highlands of southeastern New York and northern New Jersey. Journal of Field Ornithology 59: 361–368.

Titus, K., and **J. A. Mosher.** 1981. Nest-site habitat selected by woodland hawks in the central Appalachians. Auk 98: 270–281.

Zar, J. H. 1974. Biostatistical Analysis. Prentice-Hall, Englewood Cliffs, New Jersey.

Received 14 December 1991
Accepted 21 April 1993

Wetland Selection by Eared Grebes, *Podiceps nigricollis*, in Minnesota

JANET S. BOE

Department of Zoology, North Dakota State University, Fargo, North Dakota
Present address: Minnesota Biological Survey, Minnesota Department of Natural Resources, Deer River Ranger District, Box 308, Deer Rivers, Minnesota 56636

Boe, Janet S. 1992. Wetland selection by Eared Grebes, *Podiceps nigricollis*, in Minnesota. Canadian Field-Naturalist 106(4): 480–488.

In 1986, I studied wetland selection by Eared Grebes (*Podiceps nigricollis*) in Minnesota by comparing a group of wetlands used for breeding by grebes (n = 23) to a stratified random sample of unused wetlands (n = 26) in the same or nearby counties. Incidental observations made during the 1987-1989 field seasons pertinent to wetland selection are also included. Eared Grebes showed a preference for Type 4 wetlands that were > 30 ha in size and that contained 42-100% ($\bar{x}$= 78%) open water. Used wetlands were shallower and had more submergent vegetation and less treed perimeter than did unused wetlands. They were also less likely to have a public access than were unused wetlands, and they received less human use in the summer. In the drought of 1988, grebes left small wetlands and formed larger-than-usual breeding colonies on large wetlands. In 1989, two colonies were found on wetlands that were recently reflooded following managed drawdowns. Eared Grebes regularly occur, and sometimes nest, on sewage lagoons and on the most alkaline wetland in the state. The maintenance of wetland quantity, diversity, and dynamism is important to the continued reproductive success of Eared Grebes in Minnesota.

Key Words: Eared Grebe, *Podiceps nigricollis*, wetland selection, Minnesota, habitat selection.

Habitat selection may involve choices at several levels, and different features of the habitat may be important at different levels of selection (Johnson 1980; Wiens and Rotenberry 1981; Burger 1985). In this paper, I report on the selection of breeding wetlands by Eared Grebes (*Podiceps nigricollis*), part of a larger study of Eared Grebe habitat selection (Boe 1991) that also included collection of data on colony site and nest site selection.

Eared Grebes may be the most numerous grebe worldwide (Johnsgard 1987), yet relatively few quantitative studies of their nesting ecology are found in scientific literature. They are invertebrate-feeding waterbirds (Wetmore 1924) that build over-water nests in colonies on shallow, eutrophic wetlands throughout western North America (Palmer 1962). Colony sites change frequently within and among wetlands in response to changing water and vegetation conditions (Cramp and Simmons 1977). Vegetation at colony sites may include stands of emergents or surface mats of submergents (Munro 1941). Eared Grebes are weak fliers that require a long, running take-off from the surface of the water and take flight infrequently (Johnsgard 1987). Nesting adults and broods usually do not move from pond to pond, thus the wetland must supply food for the entire colony of adults during incubation and for both adults and young until the young fledge. Eared Grebes are one of the most halophilic of bird species and are well-protected from salt overload by physiological and behavioral adaptations (Jehl 1988).

Study Area

This study was conducted in western and southern Minnesota, at the extreme eastern edge of the Eared Grebe breeding range in North America (Palmer 1962). The area lies in Minnesota's grassland formation and was dominated by tallgrass prairie in presettlement times (Wendt 1984); it is now part of the corn belt, with 83% of the land cultivated (Heiskary and Wilson 1989).

The southern part of this area is an extension of the prairie pothole region, lying in Wisconsinan glacial deposits (Winter 1989). The northern part lies in the Red River Valley, a flat bed of Glacial Lake Agassiz (Waters 1977). Wetland drainage in this area, primarily for agriculture, has been extensive (Johnston 1989). Most wetlands in Minnesota's prairie pothole region are shallow and hypereutrophic, with high levels of phosphorus and low Secchi transparencies (Heiskary and Wilson 1989). The area receives an average of 61 cm of precipitation during the year, about 60% of this falling from May through September. The mean June temperature at Morris (45° 35' N, 95° 55' W) in western Minnesota is 19° C. In 1986, snowfall was near or slightly below normal from January through March, and summer temperatures were near normal, but monthly precipitation was from 1.5 to 8.0 cm above normal in April, June, July, and September and slightly below normal in May and August. Monthly precipitation was near normal in May of 1987 but from 3.6 to 5.0 cm below normal June through August. In 1988, pre-

cipitation was from 3.0 to 8.4 cm below normal May through July and 3.7 cm above normal in August. Monthly precipitation during the 1989 field season ranged from 2.5 cm above normal to 2.4 cm below normal (National Oceanic and Atmospheric Administration 1986-1989).

Counties in the study area (n = 25) held from 7 to 1048 lake basins greater than 4 ha in size, and county lakes covered an average of 5.01 ha/km^2 (SD = 4.22) (Minnesota Department of Conservation 1968).

Methods

I compared the characteristics of a group of wetlands used for nesting by Eared Grebes in one or more years from 1979 through 1985 (Colonial Waterbird Database 1986, Nongame Wildlife Program, Minnesota Department of Natural Resources (DNR), St. Paul) to those of a stratified random sample of unused wetlands in the same or adjacent counties (Figure 1). Stratification was by size class (Table 1) within wetland Types 3-5 (Shaw and Fredine 1971). Type 3 wetlands are shallow, fresh marshes; Type 4 wetlands are deep, fresh marshes; and Type 5 wetlands are open, fresh, and may be fringed with a border of emergent vegetation. Comparable wetland classifications are given in Cowardin et. al (1979) and Eggers and Reed (1987). For each lake and wetland > 4 ha in the state, the

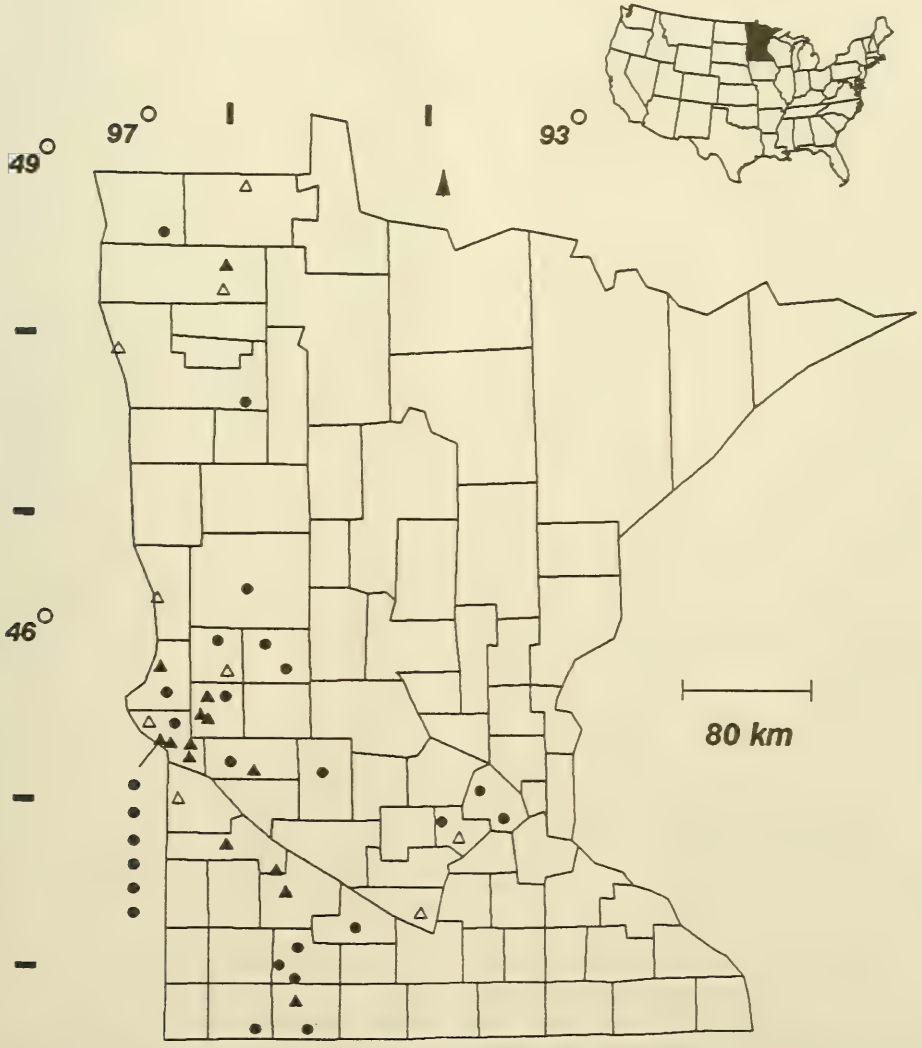


FIGURE 1. Map showing location of study wetlands in Minnesota in 1986. Closed triangles = wetlands with colonies present one or more years 1979-1985, open triangles = colonies present in 1986, closed circles = random unused wetlands.

TABLE 1. Number of wetlands in each size class (ha).

	32-121	122-404	405-2024	> 2024
Used	10	6	3	4
Unused	14	4	3	5

Division of Waters of the Minnesota DNR maintains a uniquely numbered file that contains information about the wetland, including its size and Type (sensu Shaw and Fredine 1971).

To select unused wetlands, I drew randomly from the pool of previously used or adjacent counties. Then a numbered wetland file from that county was selected randomly. If the selected wetland met the size and Type selection criteria, the wetland was placed in the group of unused wetlands. The process was continued until all size categories were filled. One wetland selected in the unused random sample was found to have a grebe colony in 1986 and was added to the used group, along with three other newly discovered wetlands with colonies. One wetland originally included in the used group was removed because breeding evidence was based on the presence of adult birds only.

I projected and traced 1986 Agricultural Stabilization and Conservation Service (ASCS) aerial slides to determine vegetation characteristics of the wetlands. Tracings were measured using manual and computerized planimeters. To assess cultural features, I used county highway maps and U.S. Geological Survey (USGS) 1:24 000 topographic maps. Wetlands were omitted from a sample if ASCS photography was not available for the wetland or if data were not available in lake files. I visited each wetland once during the summer to construct a vegetation map for use in interpreting ASCS aerial photography, census grebes, assess human use of the wetland, and record bird species present. Visits coincided approximately with ASCS flights in the area.

Submergent vegetation abundance (Table 2) was a subjective assessment made during the single, midsummer trip to each wetland. The assessments were intended originally as a check on the amount of submergent vegetation visible on aerial photography. However, I found that submergent vegetation was not visible on all aerial photographs, and no photo interpretation of submergent vegetation abundance was attempted.

For characteristics that might be expected to change from year to year, e.g., submergent vegetation abundance, only lakes with a colony in 1986 were compared with unused lakes. G tests were used to analyze 2×2 contingency tables of nominal data, and Mann-Whitney (normal approximation) or median tests were used for other comparisons.

TABLE 2. Habitat variables compared between wetlands used for nesting by Eared Grebes and randomly selected, unused wetlands.

VARIABLES	DESCRIPTION
Maximum depth[1]	Maximum depth $\leq$ 3m or > 3m
Public access	Presence or absence of designated public access
Wetland use	Presence or absence of fishing or motorboating during summer
Percent open water[2]	Percent of water free of emergents
Submergent vegetation[2]	Submergent vegetation abundance rating: 1=low, 2=moderate, 3=high
Type[1]	Wetland Type (3, 4, or 5; Shaw and Fredine 1971)
Percent emergent fringe[2]	Percent of wetland perimeter with emergent fringe
Percent treed perimeter	Percent of wetland perimeter with trees
Number of buildings	Number of homesteads or buildings within 0.2 km of wetland
Shoreline irregularity	$L/ 2 \sqrt{a \cdot pi}$), where L= shoreline length in km and a= lake area in km^2 (Wetzel 1975)
Percent road	Percent of perimeter with road or highway within 0.2 km

[1]from DNR lake files
[2]only lakes active in 1986

Differences were considered significant at $P < 0.05$. G tests were run on a microcomputer using Lotus 1-2-3 (Lotus Development Corporation 1984); Mann-Whitney and median tests and Pearson correlation coefficients were calculated using Statistix (NH Analytical Software 1986). A coefficient of community (Whittaker 1975) was calculated as an index of similarity of avian species present on the two groups of wetlands: $2w/(a+b)$, where a = the number of bird species on used wetlands, b = the number of species on unused wetlands, and w = the number of species present on both.

The term colony will be used in this paper to refer not only to the collection of birds nesting in a group (Kushlan 1986a) but also to the collection of nests. A colony site is the place on a wetland where colonial nesting takes place, and a breeding wetland is the wetland on which the colony site is located. Even though a wetland differs technically from a lake (Cowardin et al. 1979), the two terms will be used interchangeably here because many of these wetlands have been named "lakes."

During 1987-1989, nests were marked in 12 colonies on nine wetlands to examine colony site and nest site selection (Boe 1991). Incidental observations from these years pertinent to wetland selection are included in this paper.

Results

Quantitative Comparisons of Habitat Variables

Used wetlands ranged in size from 33 to 3785 ha, and unused ranged from 36 to 5793 ha. The coefficient of community (Whittaker 1975), calculated using data from 23 used wetlands and 26 unused wetlands, was 0.75 (a = 34, b = 35, w = 26). The most common species on used lakes (found on 13-17 lakes) were American Coots (*Fulica americana*), Ruddy Ducks (*Oxyura jamaicensis*), American White Pelicans (*Pelecanus erythrorhynchos*), Great Blue Herons (*Ardea herodias*), and Black Terns (*Chlidonias niger*). The most common species on unused lakes (found on 5-9 lakes) were Black Terns, American Coots, Great Blue Herons, American White Pelicans, and Mallards (*Anas platyrhynchos*).

For 12 censused colonies in this study, colony size was positively correlated ($r_p = 0.86$, $P < 0.001$) with wetland size. The distribution of wetland Types used by Eared Grebes was significantly different from that of unused wetlands (Figure 2). Used wetlands were generally Type 4, whereas unused wetlands were most often Type 5. There also was more submergent vegetation on used versus unused wetlands (Table 3).

Wetland use by Eared Grebes was negatively associated with deep water, with designated public accesses, with summer fishing and motorboating (Table 4), and with treed wetland perimeters (Table 5). Most lakes in this study had > 50% open water; no significant difference between used and unused wetlands was detected (Table 5). The difference in the number of perimeter buildings between used (n = 21) and unused (n = 23) wetlands was not quite significant overall (median test: $\chi^2 = 3.34$, df = 1, P = 0.07). However, all four wetlands surrounded by the most buildings (122-551 structures) were unused.

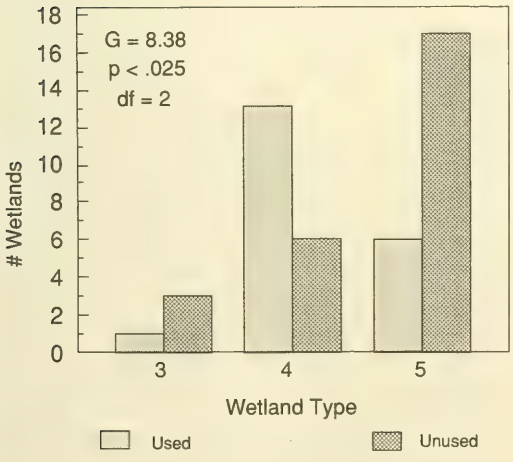


FIGURE 2. Classification of used and random unused wetlands by Type (Shaw and Fredine 1971) based on information in Minnesota DNR lake files.

TABLE 3. Submerged vegetation abundance ratings of wetlands that held colonies in 1986 (used) and a stratified random sample of unused wetlands.[1]

	Low	Medium	High
Used	1	2	5
Unused	14	7	2

[1]G = 10.15, P < 0.01, df = 2

There was no difference in the percent of the perimeter with a nearby road or highway between the two groups, nor was there a significant difference in the percent of wetland perimeter with emergent fringe (Table 5). There was no significant difference in the index of shoreline irregularity (Table 5) between used and random sample wetlands.

Other Outside Influences on Wetland Selection

In 1986, two colonies were located on mats of submergent vegetation growing in two sewage water treatment ponds [East Grand Forks in Polk County (47° 58' N, 97° 01' W) and Breckenridge in Wilkin County (46° 17' N, 96° 34' W]. Colonies were also noted on the Breckenridge ponds in 1980, 1981, and 1984, and on the East Grand Forks ponds in 1982, 1985, and 1987 (Colonial Waterbird Database 1988, Nongame Wildlife Program, Minnesota DNR, St. Paul). Salt Lake in Lac Qui Parle County (44° 58' N, 96° 27' W) is the most alkaline lake in Minnesota and has a salinity about one third that of seawater (Minnesota DNR 1977). Eared Grebes nested on the lake in 1961, 1971, 1974, 1978, 1984-1986, and 1988 (Colonial Waterbird Database 1988, Nongame Wildlife Program, Minnesota DNR, St. Paul).

During 1988, when a severe drought affected Minnesota and other states in the midwest (Trenberth et al. 1988), grebes were often observed on small wetlands (< 300 ha) in May and early June. Later in the summer, few grebes were found there, and many wetlands checked for colonies were drying rapidly. Two of the largest colonies ever found in the state were recorded during 1988; both were on large (> 3000 ha) wetlands (583 nests at Thief Lake in Marshall County (48° 30' N, 95° 55' W), 325 nests at Swan Lake in Nicollet County (44° 10' N, 94° 15' W).

In 1989, two colonies were found on managed wetlands that were recently reflooded following drawdowns. These colonies were located in a live willow (Peach-leaved, *Salix amygdaloides*, and Sandbar, *S. exigua*) and Cottonwood (*Populus deltoides*) stand at Ash Lake in Grant County (46° 03' N, 96° 08' W) and in dead goosefoot (Coast Blite, *Chenopodium rubrum*) at Mud Lake in Traverse County (45° 50' N, 96° 35' W); no beds of submerged aquatic macrophytes were seen in either wetland.

TABLE 4. Variables, number of used and unused wetlands with (+) or without (-) listed characteristics, and significance of differences (S- = significant with used wetlands less than unused wetlands).

	Used		Unused				
Variable	+	-	+	-	G	P	Sig.
Public access	3	20	13	13	8.05	< 0.005	S-
Wetland use (fishing)	1	22	13	13	14.36	< 0.001	S-
Maximum depth > 3 m	2	12	12	11	5.76	< 0.05	S-

TABLE 5. Variables, test statistics, and significance of differences (NS = not significant, S- = significant with used wetlands less than unused wetlands).

	Used			Unused					
Variable	n	$\bar{x}$	SE	n	$\bar{x}$	SE	Z	P	Sig.
% Open water	8	77.50	8.31	25	68.43	7.53	0.40	0.69	NS
% Emergent fringe	9	60.33	14.68	25	38.00	8.15	0.92	0.36	NS
% Treed perimeter	20	32.45	7.89	25	64.96	6.78	2.79	0.005	S-
Shoreline irregularity	19	1.80	0.17	24	1.85	0.14	0.16	0.87	NS
% Road	23	26.70	4.80	25	30.00	5.94	0.08	0.93	NS

Of 15 wetlands that were checked during each of the four years of this study, three were occupied during all four years, one was occupied in three of the four years, four were used during two of the four years, and seven were active for only one year (Colonial Waterbird Database 1988, Nongame Wildlife Program, Minnesota DNR, St. Paul; personal observation). For wetlands active in more than one year, colony sites changed each year. Frequency of use and wetland size were positively correlated (r_p = 0.62, $P < 0.01$).

Discussion

Bird species seen on used versus unused wetlands showed a high degree of similarity, as might be expected for wetlands in the same Type range and in the same part of the state.

Wetlands used for breeding by Eared Grebes were generally Type 4 and > 30 ha in size, with a maximum depth ≤ 3 m, no public access, little or no summer use by humans, and greater than 50% open water. Some of the variables measured are interdependent, e.g., submergent vegetation rating likely determines wetland use and the number of public accesses, as humans are not likely to choose for boating wetlands that have dense beds of submergent vegetation.

Vegetation changes rapidly with fluctuations in the water regime in marshes (Weller and Frederickson 1973). Drastically fluctuating water levels are characteristic of wetlands in the prairie pothole region (Kantrud et al. 1989), and the overall suitability of a wetland may change markedly from year to year. Eared Grebes may respond to these changes in vegetation and water regimes by using different wetlands or different locations on the same wetland from year to year.

Wetland Size, Type, and Depth

Yocom et al. (1958) and Breault (1990) reported a positive association between the size of a wetland and the number of Eared Grebe nests on the wetland. Their observations were supported by this study. Other authors have reported observing Eared Grebes nesting on wetlands smaller than those on which grebes in Minnesota have been found. Faaborg (1976) studied wetland selection by Pied-billed Grebes (*Podilymbus podiceps*), Horned Grebes (*Podiceps auritus*), and Eared Grebes near Kenmare, North Dakota, and found that Eared Grebes accounted for 218 of 235 grebe pairs nesting on 7 large (19.6 to 128.9 ha), open wetlands. On 67 small ponds (< 7.3 ha), Eared Grebes accounted for only 3 of 78 grebe pairs. Sealy (1985) reported finding 1-2 pairs with broods on 2 wetlands 0.2 and 2.5 ha in size in Saskatchewan. Breault (1990) found Eared Grebes in British Columbia nesting on wetlands that ranged in size from 0.7 to 716.3 ha ($\bar{x}$= 103.6 ha, n = 29). Small wetlands are less common in southern and western Minnesota than they are farther west in the pothole region (G. Krapu, personal communication), probably because the rich soils have made agriculture profitable, leading to the drainage of 99% of the wetland area in this part of the state (Minnesota Environmental Quality Board 1988, in Johnston 1989). Dahl (1990) reported that artificially drained agricultural land was much more abundant in the eastern half of the U.S. than in the western

half. Small wetlands are often easier to drain than are large wetlands and are therefore the first to disappear.

Faaborg (1976) suggested that competition among grebe species may result in segregation by wetland size. In the center of the prairie pothole region, where the breeding ranges of five grebe species overlap (Western, *Aechmophorus occidentalis*; Horned; Red-necked, *Podiceps grisegena*; Pied-billed; and Eared), segregation by wetland size may be important, especially among the more piscivorous species. In western Minnesota, however, breeding Horned Grebes are rare (Coffin and Pfannmuller 1988), and Red-necked Grebes nest only in low densities (Johnsgard 1987), making competition with Eared Grebes less likely. Pied-billed Grebes often nest on the same wetlands as do Eared Grebes, although they are also often found on smaller wetlands. Western and Eared Grebes frequently form mixed colonies (G. Nuechterlein, personal communication; personal observations), which suggests that, here at least, either diets separate the species, or shared foods are abundant.

Faaborg (1976) found water permanence less important to wetland selection than wetland size and cover-type. However, selection by Eared Grebes of Type 4 wetlands in this study suggests that they require water of sufficient depth over enough weeks to nest and raise young. Seasonal and semipermanent wetlands represent the primary wetland habitats for breeding waterfowl (Stewart and Kantrud 1973). Rich soils (Stoudt 1971) and agricultural use of surrounding land (Dwyer 1970) contribute to a high level of nutrients and abundant invertebrates in these wetlands. Eared Grebes are foot-propelled divers that take invertebrate food from the bottom of a wetland, from the water column, or from structures in the water (Jehl 1988). They escape potential predators by diving or swimming. A certain minimum water depth may be required for feeding and escape.

Several problems are associated with nesting in deeper water. Water depth may determine the availability of vegetation to which nests could be anchored. As water depth increases, plant communities in a wetland change; emergent vegetation that grows in shallow water may be replaced by different emergent species and submergent vegetation (Kantrud et al. 1989). The distribution of submergent vegetation depends, in part, upon clarity of the water (Davis and Brinson 1980). Low Secchi transparencies in western Minnesota lakes (Heiskary and Wilson 1989) suggest that submergent vegetation may be limited to shallow depths, although, in some lakes, this includes the entire basin. Also, as depth increases, wave height increases for a given fetch length (distance to nearest wavebreak) and windspeed (Camfield 1977). Since wind was the major cause of Eared Grebe nest loss from 1987-1989 (Boe 1991), breeding grebes might select shallow basins to minimize nest destruction.

Emergent and Submergent Vegetation

Like nesting waterfowl (Blindow 1986), grebes may select wetlands with abundant submergent vegetation because of the well-documented association of submerged macrophytes with abundant aquatic invertebrates (Krull 1970; Murkin 1983). In addition, dense submergent vegetation has an important wave-attenuating effect (Camfield 1977) that may contribute directly to nesting success.

Expanses of open water may be important for escape, as Eared Grebes tend to congregate in open water when disturbed (Bent 1919; personal observations). In addition, because grebes run across the water before taking low flight (Johnsgard 1987), they may require a certain minimum expanse of open water to take flight.

The emergent fringe (usually *Typha* spp.) of a wetland is limited to shallow water areas (< 0.6 m deep) close to shore (Eggers and Reed 1987). Grebes in this study nested on mats or in emergents farther from shore than the emergent fringe. The presence of an emergent fringe appeared to be unimportant in the selection of a breeding wetland.

Wetland Perimeter

The selection by Eared Grebes of wetlands with limited treed perimeter may be related to their flight requirements. Diving ducks, American Coots, and Horned, Pied-billed, and Red-necked grebes in Manitoba showed a preference for wetlands that had an incompletely wooded perimeter, possibly because trees interfered with takeoff and landing (Dwyer 1970). Irregular shorelines may be attractive to territorial birds requiring visual obstructions but are probably unimportant to highly gregarious Eared Grebes nesting well out on the wetland.

Outside Influences

Sewage stabilization ponds are nutrient-rich aquatic environments that have abundant aquatic invertebrate populations that attract waterfowl (Moulton et al. 1976; Piest and Sowls 1985). Their high organic base (imported sewage) provides conditions favorable to midge (Chironomidae) and Cladocera (*Daphnia* spp.) production (Swanson 1977). Eared Grebes often feed on these ponds and may nest on them in years in which a dense bed of submergent vegetation develops. Managed wetlands may be temporarily drained to mimic natural drawdown, which releases nutrients in decaying plant material and permits germination of seeds of emergent macrophytes (Weller 1987). Following reflooding, the surface area provided by flooded litter that accumulated during drawdown may be an important contributor to high invertebrate productivity (Murkin 1989). Of Eared Grebe breeding wetlands observed during the four field seasons of this research project,

only two lacked beds of submergent vegetation; these were two wetlands recently reflooded following managed drawdowns. An abundant invertebrate food supply, whether related to imported sewage, submergent vegetation, or flooded litter, is important for invertebrate-feeding grebes, especially since they are restricted to foraging in their breeding wetland.

The movement of grebes from small wetlands to large wetlands in drought years emphasizes the importance of large wetlands to this species. These large wetlands also hold large colonies in normal years and may act as source habitats (productive areas that contribute recruits to populations in less productive habitats) (Pulliam 1988).

As colonial overwater nesters, Eared Grebes are vulnerable to boat traffic and may select wetlands in which this disturbance is minimal. Based on observations in this study, my impression was that, in most cases, as long as humans stayed off the water, their proximity to a breeding wetland was irrelevant.

The selection of eutrophic wetlands that have abundant submergent vegetation and the use of invertebrate-rich sewage treatment ponds and recently reflooded wetlands suggest that food supply is important in the selection of a breeding wetland by Eared Grebes, but food availability was not directly measured in this study.

Implications

Although a particular wetland may not be used for breeding in consecutive years, it retains its importance to local Eared Grebe populations by its inclusion in the pool of wetlands that, in one year or another, serve as breeding wetlands. Small, isolated wetlands and large wetland complexes may both have an important role to play in the maintenance of aquatic bird populations (Kushlan 1986b). The habitat requirements of aquatic birds should be addressed in wetland management plans, and documentation of the use by Eared Grebes and other typical aquatic bird species should help focus attention on wetland conservation.

Continued wetland drainage, water diversion for agriculture, and the maintenance of high water levels to support recreational fishing cloud the future of multi-species wildlife management on western Minnesota wetlands. Any efforts to prevent wetland drainage, including enactment and strict enforcement of potent antidrainage legislation, should help maintain the variety of wetlands required by Eared Grebes. Conversion of wetlands into fishing lakes is a temptation in areas that are far from deepwater habitats. However, the status of Minnesota's wetlands should be weighed against the abundance, albeit unequal distribution, of fishing lakes in the state before any further conversions are considered. The long-term maintenance of primary and secondary productivity in wetlands used by grebes and other invertebrate-feeding birds, including breeding waterfowl, requires that dynamism be retained in managed systems as well as in unmanaged wetlands (Frederickson and Reid 1990).

Acknowledgments

I thank Kristie Prahl, John Schladweiler, Martha Marquardt, Wendy Krueger, Gary Nuechterlein, and Deborah Buitron for field assistance. Lee Westfield and the Office of Resource Assessment of the Division of Forestry, Minnesota Department of Natural Resources, provided valuable advice and equipment. Sandy Fecht cheerfully sorted through Department of Natural Resources lake files. Research for this paper was conducted as part of a graduate program in the Zoology Department at North Dakota State University. I thank my major advisor, Gary Nuechterlein, and my advisory committee, Deborah Buitron, Gary Clambey, James Grier, Douglas Johnson, and Rhonda Magel, for guidance and for reading earlier drafts of this manuscript. In addition, this paper benefitted from the comments of two reviewers. Financial support was provided by the Frank M. Chapman Memorial Fund of the American Museum of Natural History, by a Sigma Xi research grant, by North Dakota State University (in the form of a teaching assistantship), and by the Nongame Wildlife Program of the Minnesota Department of Natural Resources.

Literature Cited

Bent, A. C. 1919. Life histories of North American diving birds. Smithsonian Institution. United States National Museum Bulletin 107. United States Government Printing Office, Washington, D.C. 239 pages. [Dover edition.]

Blindow, I. 1986. Undervattensvaxter viktiga i fagelsjoar. Fauna Flora 81: 235–243.

Boe, J. S. 1991. Breeding habitat selection by eared grebes in Minnesota. Ph.D. dissertation, North Dakota State University, Fargo. 242 pages.

Bratton, S. P. 1990. Boat disturbance of Ciconiiformes in Georgia estuaries. Colonial Waterbirds 13: 124–128.

Breault, A. M. 1990. Breeding distribution, habitat selection and factors affecting coloniality in eared grebes in British Columbia. M.Sc. thesis, University of British Columbia, Vancouver. 125 pages.

Burger, J. 1985. Habitat selection in temperate marsh-nesting birds. Pages 253-281 *in* Habitat selection in birds. *Edited by* M. L. Cody. Academic Press, Orlando, Florida.

Camfield, F. E. 1977. A method for estimating wind-wave growth and decay in shallow water with high values of bottom friction. U.S. Army Corps of Engineers, Coastal Engineering Research Center, Fort Belvoir, Virginia. 34 pages.

Coffin, B. and **L. Pfannmuller.** *Editors.* 1988. Minnesota's endangered flora and fauna. University of Minnesota Press, Minneapolis. 473 pages.

Cowardin, L. M., V. Carter, F. C. Golet, and **E. T. Laroe.** 1979. Classification of wetlands and deepwater habitats of the United States. Office of Biological

Services, U.S. Department of the Interior, Washington, D.C. 103 pages.

Cramp, S. C., and **K. E. L. Simmons.** *Editors.* 1977. Handbook of the birds of Europe, the Middle East and North Africa: the birds of the Western Palearctic. Volume 1. Oxford University Press, London. 722 pages.

Dahl, T. E. 1990. Wetland losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, D.C. 21 pages.

Davis, G. J., and **M. M. Brinson.** 1980. Responses of submersed vascular plant communities to environmental changes. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. 15 pages.

Dwyer, T. 1970. Waterfowl breeding habitat in agricultural and nonagricultural land in Manitoba. Journal of Wildlife Management 34: 130–136.

Eggers, S. D., and **D. M. Reed.** 1987. Wetland plants and plant communities of Minnesota and Wisconsin. U.S. Army Corps of Engineers, St. Paul, Minnesota. 201 pages.

Faaborg, J. 1976. Habitat selection and territorial behavior of the small grebes of North Dakota. Wilson Bulletin 88: 390-399.

Frederickson, L. H., and **F. A. Reid.** 1990. Impacts of hydrologic alteration on management of freshwater wetlands. Pages 71-90 *in* Management of dynamic ecosystems. *Edited by* J. M. Sweeny. North Central Section, The Wildlife Society, West Lafayette, Indiana.

Heiskary, S. A., and **C. B. Wilson.** 1989. The regional nature of lake water quality in Minnesota: an analysis for improving resource management. Journal of the Minnesota Academy of Science 55: 71–77.

Jehl, J. R., Jr. 1988. Biology of the eared grebe and Wilson's phalarope in the nonbreeding season: a study of adaptations to saline lakes. Studies in Avian Biology. Number 12. Cooper Ornithological Society. 74 pages.

Johnsgard, P. A. 1987. Diving birds of North America. University of Nebraska Press, Lincoln. 292 pages.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61: 65–71.

Johnston, C. A. 1989. Human impacts to Minnesota wetlands. Journal of the Minnesota Academy of Science 55: 120–124.

Kantrud, H. A., and **R. E. Stewart.** 1984. Ecological distribution and crude density of breeding birds on prairie wetlands. Journal of Wildlife Management 48: 426–437.

Kantrud, H. A., G. L. Krapu, and **G. A. Swanson.** 1989. Prairie basins of the Dakotas: a community profile. U.S. Fish and Wildlife Service Biological Report 85(7.28). 116 pages.

Krull, J. N. 1970. Aquatic plant-macroinvertebrate associations and waterfowl. Journal of Wildlife Management 34: 707–718.

Kushlan, J. A. 1986a. Colonies, sites, and surveys: the terminology of colonial waterbird studies. Colonial Waterbirds 9: 119–120.

Kushlan, J. A. 1986b. The management of wetlands for aquatic birds. Colonial Waterbirds 9: 246–248.

Lotus Development Corporation. 1984. Lotus 1-2-3. Cambridge, Massachusetts.

Minnesota Department of Conservation. 1968. An inventory of Minnesota lakes. Bulletin Number 25. Division of Water, Soils, and Minerals, St. Paul. 498 pages.

Minnesota Department of Natural Resources. 1977. Management plan for Salt Lake Wildlife Management Area and Scientific and Natural Area. Division of Fish and Wildlife. 8 pages.

Moulton, D. W., W. I. Jensen, and **J. B. Low.** 1976. Avian botulism epizootiology on sewage oxidation ponds in Utah. Journal of Wildlife Management 40: 735–742.

Munro, J. A. 1941. Studies of waterfowl in British Columbia: the grebes. Occasional Paper Number 3. British Columbia Provincial Museum. 71 pages.

Murkin, H. R. 1983. Responses of aquatic macroinvertebrates to prolonged flooding of marsh habitats. Ph.D. dissertation, Utah State University, Logan. 126 pages.

Murkin, H. R. 1989. The basis of food chains in prairie wetlands. Pages 316-338 *in* Northern prairie wetlands. *Edited by* A. van der Valk. Iowa State University Press, Ames.

National Oceanic and Atmospheric Administration. 1986-1989. Local climatological data. National Climatic Data Center, Asheville, North Carolina.

NH Analytical Software. 1986. Statistix. NH Analytical Software, St. Paul, Minnesota.

Palmer, R. S. *Editor* 1962. Handbook of North American birds. Volume 1. Yale University Press, New Haven. 567 pages.

Piest, L. A., and **L. K. Sowls.** 1985. Breeding duck use of a sewage marsh in Arizona. Journal of Wildlife Management 49: 580–585.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. American Naturalist 132: 652–661.

Sealy, S. G. 1985. Diving times and parental feeding of young in solitarily nesting eared grebes. Colonial Waterbirds 8: 63–66.

Shaw, S. P., and **C. G. Fredine.** 1971. Wetlands of the United States. Circular 39. U.S. Fish and Wildlife Service. 67 pages.

Stewart, R., and **H. A. Kantrud.** 1973. Ecological distribution of breeding waterfowl populations in North Dakota. Journal of Wildlife Management 37: 39–50.

Stoudt, J. H. 1971. Ecological factors affecting waterfowl production in the Saskatchewan parklands. U.S. Department of the Interior, Bureau of Sport Fisheries and Wildlife. Resource Publication 99. 58 pages.

Swanson, G. A. 1977. Diel food selection by Anatinae on a waste-stabilization system. Journal of Wildlife Management 41: 226–231.

Trenberth, K. E., G. W. Granstator, and **P. A. Arkin.** 1988. Origins of the 1988 North American drought. Science 242: 1640–1645.

Waters, T. F. 1977. The streams and rivers of Minnesota. University of Minnesota Press, Minneapolis. 373 pages.

Wendt, K. M. 1984. A guide to Minnesota prairies. Minnesota Department of Natural Resources, St. Paul. 71 pages.

Weller, M. W. 1987. Freshwater marshes. Second edition. University of Minnesota Press, Minneapolis. 150 pages.

Weller, M. W., and **L. H. Frederickson.** 1973. Avian ecology of a managed glacial marsh. Living Bird 12: 269–291.

Wetmore, A. 1924. Food and economic relations of North American grebes. Bulletin 1196. U.S. Department of Agriculture. 22 pages.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Company, Philadelphia, Pennsylvania. 743 pages.

Whittaker, R. H. 1975. Communities and ecosystems. Second edition. Macmillan Publishing Company, New York, New York. 385 pages.

Wiens, J. A., and **J. T. Rotenberry.** 1981. Habitat associations and community structure of birds in shrubsteppe environments. Ecological Monographs 51: 21–41.

Winter, T. C. 1989. Hydrologic studies of wetlands in the northern prairie. Pages 16-54 *in* Northern prairie wetlands. *Edited by* A. van der Valk. Iowa State University Press, Ames.

Yocom, C. F., S. W. Harris, and **H. A. Hansen.** 1958. Status of grebes in eastern Washington. Auk 75: 36–47.

Received 2 January 1992
Accepted 10 September 1993

Recent Sightings of Harbour Porpoises, *Phocoena phocoena*, near Point Barrow, Alaska

ROBERT S. SUYDAM AND JOHN CRAIGHEAD GEORGE

Department of Wildlife Management, North Slope Borough, P.O. Box 69, Barrow, Alaska 99723

Suydam, Robert S., and John Craighead George. 1992. Recent sightings of Harbour Porpoises, *Phocoena phocoena*, near Point Barrow, Alaska. Canadian Field-Naturalist 106(4): 489–492.

Harbour Porpoises occur regularly in the north Pacific Ocean and the Bering Sea and occasionally in the Chukchi Sea during the ice-free months. Point Barrow, Alaska is considered to be near the northern limit of distribution for this species. We have obtained nine records from the vicinity of Point Barrow between 1985 and 1991. Harbour Porpoises were found entangled in subsistence fishing nets, seen live or found dead on the beach. These records indicate a regular use of the northeastern Chukchi Sea and extreme western Beaufort Sea. The reasons for their occurrence near Point Barrow are unknown but the relative abundance of fish in coastal arctic lagoons may attract Harbour Porpoises northward.

Key Words: Harbour Porpoise, *Phocoena phocoena*, distribution, coastal lagoons, entanglement.

Harbour Porpoises, *Phocoena phocoena*(L.), inhabit cold-temperate, subarctic waters in the northern hemisphere (Leatherwood et al. 1982; Gaskin 1984) and are known to occur regularly in the North Pacific Ocean, the Bering Sea and the Sea of Okhotsk (Tomilin 1957; Leatherwood et al. 1983; Gaskin 1984). Their distribution in higher latitudes is seasonally limited by ice-covered waters. In the Bering Sea, movements of Harbour Porpoise occur north in summer and south in fall (Leatherwood et al. 1983; Gaskin 1984). Cold temperatures have been suggested as a limiting factor to Harbour Porpoise distribution (Bee and Hall 1956) and rapid freezing conditions pose a threat due to ice-entrapment (*see* Tomilin 1957). Harbour Porpoise are known to come into contact with sea ice (Fay 1974) and cold water –1°C (D. E. Gaskin, University of Guelph, Guelph, Ontario, personal communication).

Harbour Porpoises have been described as chance visitors to the Chukchi and Beaufort Seas (Leatherwood et al. 1982), whereas others have suggested that they occur regularly in the coastal Chukchi Sea during ice-free months (Tomilin 1957; Lowry et al. 1982; *in* Leatherwood et al. 1983). Fall season marine mammal surveys conducted in the Chukchi and Beaufort Seas from 1982 to 1991 have failed to detect Harbour Porpoises (Moore and Clarke 1990) but other land-based and ship surveys have reported occasional sightings (Bee and Hall 1956; Blaylock and Erikson 1983; Fadely et al. 1989; K. Frost, Alaska Department of Fish and Game, Fairbanks, Alaska, personal communication). There is one record of two animals from the MacKenzie River Delta, 800 km east of Point Barrow (Van Bree et al. 1977; *in* Gaskin 1984) and a single record at the U.S. National Museum of a specimen taken in 1916 from Wrangel Island (Gaskin 1984). The relatively low number of sightings is likely due to two factors; the small size and the shy and inconspicuous nature of the Harbour Porpoise (Leatherwood et al. 1983; Brueggeman et al. 1987), and the presumed small number of animals occurring north of the Bering Strait.

The northern limit of Harbour Porpoise distribution is defined by the Arctic ice margin (Gaskin 1984). Point Barrow, Alaska, at the boundary of the northeastern Chukchi Sea and the western Beaufort Sea, is near this northern limit. This paper presents evidence of the regular occurrence of Harbour Porpoises in the northeastern Chukchi and western Beaufort Seas.

Recent Sightings

We have obtained nine records of Harbour Porpoise in the vicinity of Point Barrow, between 1985 and 1991, as summarized in Table 1; locations are in Figure 1. Two of the records are of live sightings, one record is of three animals found dead on the beach and the remaining six records are of eight animals entangled in subsistence fishing nets in Elson Lagoon (Figure 1). Six of these entangled animals were caught in 1991. All of the entangled porpoises were caught in shore set gill nets (10 cm mesh of braided nylon or monofilament) of up to 100 m in length.

The porpoises entangled in 1985, 1987 and two of the animals from 1991 were externally examined. All were grayish-brown in color dorsally and light in color ventrally and had a distinct dark stripe connecting the flipper with the corner of the mouth. Two of the animals were males and two were females. The males were 135 cm and 142 cm long and the females were 139 cm and 184 cm long. The 184 cm long female had an axillary girth of 88 cm and a mass of 64.9 kg.

Table 1. Sightings of Harbour Porpoise in the Chukchi and Beaufort Seas

Date	Location	Lat/Long	Number	Comments	Reference
1930	Kugrua Lagoon	70°47'N 159°17'W	2	Live sighting	Bee and Hall 1956
9/1/33	NE of Wainwright	70°47'N 159°39'W	1	Beach cast dead	Bee and Hall 1956
9/1/33	Atanik	70°50'N 159°21'W	1	Beach cast dead	Bee and Hall 1956
8/1/37	Kugrua Lagoon	70°47'N 159°17'W	2	Live sighting	Bee and Hall 1956
1950-52	Barrow	71°17'N 156°48'W	several	Live sighting	Bee and Hall 1956
8/6/52	Elson Lagoon	71°21'N 156°20'W	1	Entangled	Bee and Hall 1956
8/23/52	Elson Lagoon	71°21'N 156°20'W	1	Entangled	Bee and Hall 1956
8/21/85	Elson Lagoon	71°21'N 156°20'W	1	Entangled	This paper
10/4/86	N. of Barrow	71°+N 156°20'W	several	Live sighting	This paper
8/1/87	Elson Lagoon	71°20'N 156°35'W	1	Entangled	This paper
8/15/87	Kugrua River	70°40'N 159°10'W	3	Beach cast dead	This paper
8/15/91	Elson Lagoon	71°21'N 156°20'W	3	Entangled	This paper
8/18/91	Elson Lagoon	71°21'N 156°20'W	1	Live sighting	This paper
8/18/91	Elson Lagoon	71°21'N 156°20'W	1	Entangled	This paper
8/22/91	Elson Lagoon	71°21'N 156°20'W	1	Entangled	This paper
8/28/91	Elson Lagoon	71°21'N 156°20'W	1	Entangled	This paper

Discussion

Subsistence fishermen in Barrow state that it is not uncommon for one or two porpoises to be caught each summer (W. Adams, Barrow, Alaska; and L. Elavgak, Barrow, Alaska; personal communications). Bee and Hall (1956) reported that local residents of Barrow saw Harbour Porpoises regularly but five or six was the most seen in any one year. Therefore, 1991 represents a year with a high number of Harbour Porpoises caught in subsistence fishing nets. The porpoises may have been forced into Elson Lagoon by ice that was farther south than normal for August. Typically, the area of 50% concentration of pack ice is 16 nautical miles north of the Point Barrow coast at that time (LaBelle et al. 1983). In 1991, the pack ice was in against the coast near Barrow for most of July and August.

Harbour Porpoises may move into arctic lagoons in search of food. Least Cisco (*Coregonus sardinella*), Humpback Whitefish (*Coregonus pidschian*), Rainbow Smelt (*Osmerus mordax*) and Saffron Cod (*Eleginus gracilis*) are relatively abundant in Elson Lagoon (M. Philo, North Slope Borough, Barrow, Alaska, personal communication). Bee and Hall (1956) describe two Harbour Porpoises caught by native hunters in Elson Lagoon, near Point Barrow, Alaska in 1952, a 162 cm long female and a young animal measuring 91 cm long. The stomach of the female contained bones and otoliths of whitefish. Additionally, Bee and Hall (1956) described five records of live or beach cast dead Harbour Porpoises between Wainwright and Barrow, Alaska from 1930 to 1952 (Figure 1). All were caught or found in August or September. One of these records was of two porpoises chasing fish in shallow water 3 meters from shore near the mouth of the Kugrua River (Figure 1). Further evidence of the importance of arctic lagoons for food comes from our sighting of one porpoise feeding 5 to 10 meters from shore in the northwest corner of Elson Lagoon on 18 August 1991.

The recent records from the Point Barrow area show that Harbour Porpoises regularly occur in the northeastern Chukchi and western Beaufort Seas during ice-free months. This area is considered to be near the northern limit of their range in the Pacific Ocean region. We assume they move into the area from the Bering Sea and return south with the advance of the pack ice in the fall. The reasons for these movements are unknown but, as stated above, the relative abundance of fish in the coastal arctic lagoons may attract Harbour Porpoises northward.

Acknowledgments

We thank Mike Aamodt, Sheldon Adams, Whitlam Adams, Joe Burgener, Arnold Brower, Jr., Laura Elavgak, and Sadie Neakok for providing information on sightings, standings and net caught Harbour

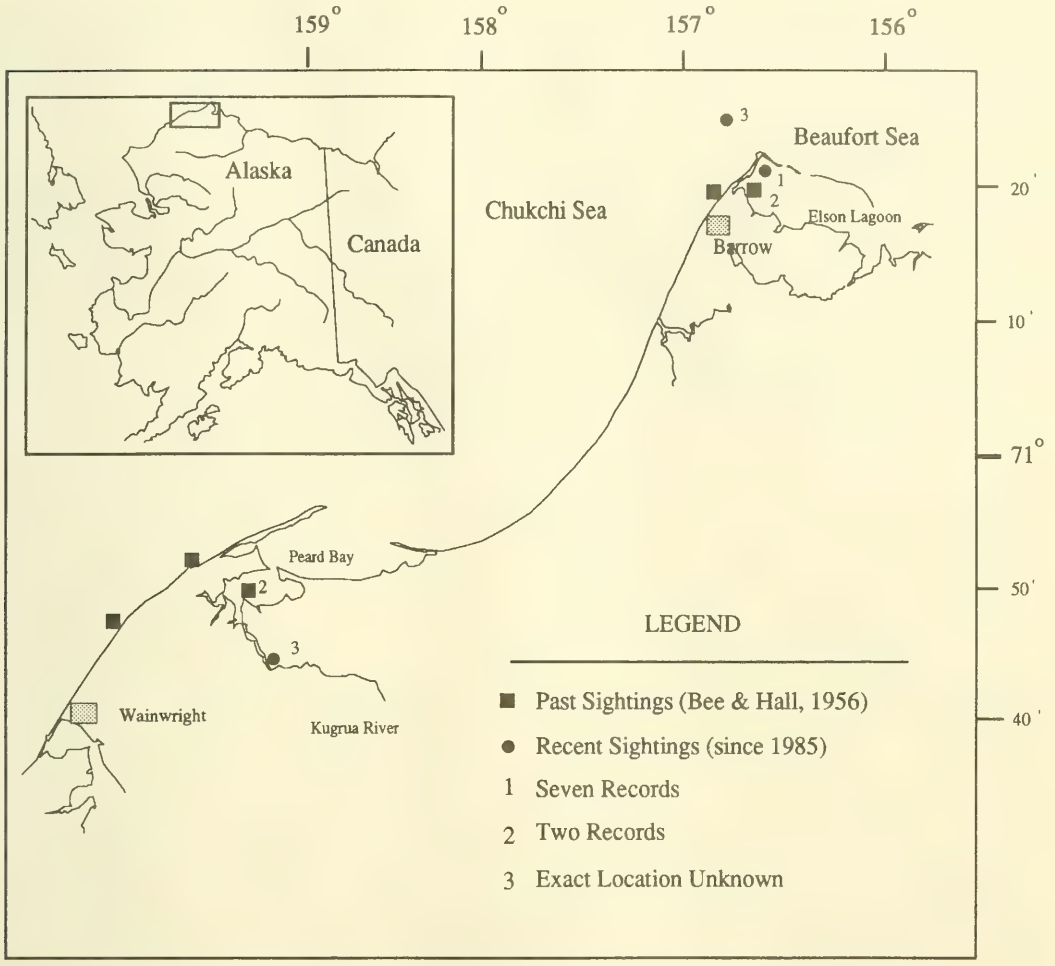


FIGURE 1. Locations of recent and past sightings of Harbour Porpoise in the Point Barrow area.

Porpoises. Kathy Frost, D. E. Gaskin, Lloyd Lowry, David Norton and two anonymous reviewers provided helpful comments on the manuscript. This project was supported by the North Slope Borough, Department of Wildlife Management, Barrow, Alaska.

Literature Cited

Bee, J. W., and **E. R. Hall.** 1956. Mammals of Northern Alaska. University of Kansas, Museum of Natural History, Lawrence. 309 pages.

Blaylock, W. M., and **D. E. Erikson.** 1983*. Marine Biology. *In* Environmental Baseline Studies; Red Dog Project. Unpublished Report by Dames and Moore to Cominco Alaska Inc. Anchorage, Alaska. 597 pages.

Brueggeman, J. J., G. A. Green, R. A. Grotefendt, and **D. A. Chapman.** 1987*. Aerial surveys of endangered cetaceans and other marine mammals in the northwestern Gulf of Alaska and southeastern Bering Sea. Pages 1–124 *in* Environmental assessment of the Alaskan Continental Shelf, final reports of principal investigators, Volume 61, Outer Continental Shelf Environmental Assessment, Anchorage, Alaska.

Fadely, B. S., J. F. Piatt, S. A. Hatch, and **D. G. Roseneau.** 1989*. Populations, productivity, and feeding habits of seabirds at Cape Thompson, Alaska. Outer Continental Shelf Study, Minerals Management Service 89–0014. U.S. Fish and Wildlife Service, Anchorage, Alaska. 429 pages.

Fay, F. H. 1974. The role of ice in the ecology of marine mammals of the Bering Sea. *In* Oceanography of the Bering Sea. *Edited by* D.W. Wood and E.J. Kelley. Institute of Marine Science, University of Alaska, Fairbanks. 383 pages.

Gaskin, D. E. 1984. The Harbour Porpoise, *Phocoena phocoena* (L.): Regional populations, status, and information on direct and indirect catches. Report to the International Whaling Commission 34: 569–586.

LaBelle, J. C., J. L. Wise, R. P. Voelker, R. H. Schulze, and **G. M. Wohl.** 1983. Alaska Marine Ice Atlas. Arctic Environmental Information and Data Center, University of Alaska, Anchorage. 302 pages.

Leatherwood, S., R. R. Reeves, W. F. Perrin, and **W. E. Evans.** 1982. Whales, dolphins, and porpoises of the eastern North Pacific and adjacent Arctic waters. National Oceanic and Atmospheric Administration Technical Report, National Marine Fisheries Service Circular 444. U.S. Department of Commerce, Washington, D.C. 245 pages.

Leatherwood, S., A. E. Bowles, and **R. R. Reeves.** 1983*. Aerial surveys of marine mammals in the southeastern Bering Sea. Pages 147–490 *in* Environmental assessment of the Alaskan Continental Shelf, final reports of principal investigators, Volume 42, Outer Continental Shelf Environmental Assessment Program, Anchorage, Alaska.

Lowry, L. F., K. J. Frost, D. G. Calkins, G. L. Swartzman, and **S. Hills.** 1982*. Feeding habits, food requirements, and status of Bering Sea marine mammals. North Pacific Fishery Management Council, Anchorage, Alaska. Document Number 19. 292 pages.

Moore, S. E., and **J. T. Clarke.** 1990*. Distribution, abundance and behavior of endangered whales in the Alaskan Chukchi and western Beaufort Sea, 1989. Outer Continental Shelf Study, Minerals Management Service 90–0051. SEACO Inc., San Diego, California. 118 pages.

Tomilin, A. G. 1957. Cetacea. *In* Mammals of the USSR and adjacent countries. *Edited by* V.G. Heptner. Translated from Russian by Israel Program for Scientific Translations (IPST Catalogue Number 1224). 717 pages.

Van Bree, P. J. H., D. E. Sergeant, and **W. Hoek.** 1977. A Harbour Porpoise, *Phocoena phocoena*(L.), from the Mackenzie River Delta, Northwest Territories, Canada. Beaufortia 26: 99–105.

* Unpublished document

Received 5 February 1992
Accepted 7 April 1993

Organochlorine Contaminants in Migrant and Resident Prey of Peregrine Falcons, *Falco peregrinus,* in Panama, Venezuela, and Mexico

URSULA BANASCH[1], J. PAUL GOOSSEN[1], ALBERTO EINSTEIN RIEZ[2], CLARK CASLER[3], AND ROMEO DOMINGUEZ BARRADAS[4]

[1]Canadian Wildlife Service, Twin Atria Bldg., 4999-98 Avenue, Edmonton, Alberta T6B 2X3
[2]Martin 3294, Herrera Province, Chitre, Panama
[3]University of Zulia, Apartado 1416, Maracaibo, 4001-A, Venezuela
[4]ECOSFERA, Apartado 219, C.P. 29200, San Cristobal de las Casas, Chiapas, Mexico

Banasch, Ursula, J. Paul Goossen, Alberto Einstein Riez, Clark Casler, and Romeo Dominguez Barradas. 1992. organochlorine contaminants in migrant and resident prey of Peregrine Falcons, *Falco peregrinus,* in Panama, Venezuela, and Mexico. Canadian Field-Naturalist 106(4): 493–498.

During 1984-1989, we collected Peregrine Falcon prey species, in the fall and the following spring, in Panama, Venezuela, and Mexico, to determine the levels of organochlorine contamination. The mean DDE levels, by country, for fall samples ranged from 0.28 to 0.68 ppm; for spring samples the DDE levels ranged from 0.02 to 1.12 ppm. The spring migrants collected in Mexico exceeded 1.00 ppm DDE, the more conservative DDE level considered sufficient in prey to produce decreased productivity in peregrines. Some species collected in the fall arrived with more than 1.00 ppm DDE in their tissues.

De 1984 à 1989, nous avons capturé des espèces qui servent de proies au faucon pèlerin au cours de l'automne et du printemps suivant au Panama, au Venezuela et au Mexique pour déterminer leur degré de contamination par les pecticides organochlorés. La concentration moyenne de DDE par pays pour les échantillons capturés l'automne a varié de 0,28 à 0,68 ppm. Pour les échantillons capturés au printemps, elle a varié de 0,02 à 1,12 ppm. Dans le cas des migrants du printemps capturés au Mexique, elle dépassait 1,00 ppm, concentration qui, selon l'estimation la plus prudente, est considérée comme suffisante chez les proies pour resulter une diminution de la productivité des faucons pèlerins. Certaines espèces capturées en automne avaient à leur arrivée plus de 1,00 ppm de DDE dans leurs tissus.

Key Words: Peregrine Falcon, *Falco peregrinus*, organochlorines, DDE, Panama, Venezuela, Mexico.

The decline of Peregrine Falcon, *Falco peregrinus,* populations in Canada, during the late 1940s to early 1960s, closely followed the increased use of DDT throughout much of North America and Europe (Newton 1979). Peakall and Kiff (1979) reported eggshell thinning and DDE residues in every egg analysed from throughout the peregrine's global range, and Bijleveld (1974) noted population declines in at least 36 countries. In North America, DDT and its major metabolite DDE alone caused peregrine population declines (Risebrough 1986; Risebrough et al. 1986; Risebrough and Peakall 1988). In Britain, Ratcliffe (1980) considered direct mortality caused by dieldrin to be of greater importance, although an increase in eggshell thicknesses was noted once DDT usage ceased (Ratcliffe 1984).

DDT, a chlorinated hydrocarbon first developed for agricultural use and for malaria control, attained more widespread use after 1947. Its breakdown product, DDE, is stable, lipophilic, and persistent (Newton 1979; Peakall and Kiff 1988). The peregrine, an upper trophic level feeder, displays intermediate sensitivity towards DDE compared with four other falcons, and exhibits population declines when DDE contamination reaches 15-20 ppm wet weight in egg contents (Peakall et al. 1975; Fyfe et al. 1976; Newton 1979). A DDE level of 1.00 ppm wet weight in prey is considered sufficient, if consumed during the breeding season, to reduce productivity in peregrine populations due to eggshell thinning (Enderson et al. 1982) but is lower than the 3.00 ppm suggested for this effect by DeWeese et al. (1986). Peregrine populations that feed on migrant prey exhibit more contamination than those feeding on resident prey (Enderson et al. 1982; Springer et al. 1984; Court et al. 1990; Fyfe et al. 1990).

The Canadian and United States governments restricted DDT in 1969 and in 1972 respectively (Kiff 1988), but peregrine populations failed to recover because the peregrine and its prey winter in Latin America, where organochlorine pesticide use continues in some countries (Henny et al. 1982; Burton and Philogene 1988). These pesticides are the least expensive commercial, broad-spectrum products available (Encalada 1985). Although production levels of pesticides in Latin America remain low, most countries import them from the United States and Europe (Burton and Philogene 1988). To better define the origin of these organochlorines used on the wintering grounds that affect the peregrine's populations, the

Canadian Wildlife Service, Western and Northern Region, together with cooperators in Surinam, Peru, Ecuador, and Costa Rica, initiated a monitoring project in 1979 through 1984 (Fyfe et al. 1990). To complete this project, sampling continued in Panama, Venezuela, and Mexico during 1984-1989.

Methods

In Panama, near Chitre, we collected at river mouths, along sandy beaches, on offshore islands, and around shrimp ponds in mangrove areas. In Venezuela, our sampling efforts covered sandy beaches, river mouths and creeks emptying into Lake Maracaibo, and the llanos, extensive grassland plains, of Apure and Portuguesa states. In Veracruz, Tabasco, and Campeche, Mexico, we sampled shorebirds along sandy beaches, on sandbars, at river mouths, and in lagoons, tidal ponds, and marshes.

Together with government agencies, universities, and private individuals, we collected North American migrants in Panama (1984 and 1985), Venezuela (1986 and 1987), and Mexico (1987 and 1988) between September and December and in the following February to April. We assumed that the difference between organochlorine levels in fall and spring would assess residues accumulated on the winter range.

In each country we attempted to select ten prey species, documented as regular winter visitors, and collected 20 individuals of each species, ten in the fall and ten in the following spring. To collect avian samples, researchers used mistnests or guns. We transported the frozen samples back to Canada by air; the Ontario Research Foundation performed all the analyses (Reynolds and Cooper 1975). When calculating the mean whole body residue levels for each country, we omitted any species pool of less than three specimens.

Results

The Peregrine Falcon prey collected in the three countries comprised 17 migrant prey species from North America and seven resident prey species.

Panama

Due to a nonfunctioning freezer, all spring samples were lost. The mean DDE level for fall migrants was 0.52 ppm (SD ± 0.52) versus 0.03 ppm (SD ± 0.01) for the three residents (Table 1). Three of the fall migrants, Long-billed Dowitcher, *Limnodromus scolopaceus*, Barn Swallow, *Hirundo rustica,* and Lesser Yellowlegs, *Tringa flavipes*, showed DDE levels in excess of 1.00 ppm.

Venezuela

The fall migrants' mean DDE level of 0.28 ppm (SD ± 0.34) did not differ significantly from 0.02 ppm (SD ± 0.02) in the spring migrants (Table 2). No spring migrants' DDE level exceeded 1.00 ppm

TABLE 1. Mean organochlorine residues in migrant and resident prey of Peregrine Falcons collected in Panama during fall 1984 (all analyses in ppm wet weight for whole body unless indicated otherwise).

Species	N[1]	DDE[2]	P,p'-DDT[3]	PCB[4]	HE[5]	Dield[6]	End[7]	A-HCH[8]	B-HCH[9]
Migrants									
Blue-winged Teal (bm)[10]	3	0.08	ND[11]	ND	<0.01	0.01	ND	<0.01	<0.01
(liver)	3	0.02	ND	ND	0.02	0.03	ND	ND	ND
Short-billed Dowitcher	5	0.69	0.02	0.58	0.06	0.10	0.20	<0.01	0.02
Long-billed Dowitcher	11	1.40	ND	0.88	0.02	0.27	ND	<0.01	0.01
Least Sandpiper	10	0.05	0.02	0.14	0.02	0.04	0.02	ND	0.01
Semipalmated Sandpiper	10	0.03	0.02	0.58	0.01	0.02	0.01	ND	0.02
Western Sandpiper	13	0.22	0.03	0.51	0.06	0.04	0.02	0.01	0.03
Greater Yellowlegs	4	0.14	ND	0.23	0.01	0.01	<0.01	<0.01	0.01
Lesser Yellowlegs	10	1.48	ND	0.80	0.05	0.04	<0.01	<0.01	0.02
Willet	10	0.42	ND	0.40	ND	ND	ND	ND	ND
Spotted Sandpiper	10	0.33	0.01	0.21	0.04	0.06	0.01	ND	0.01
Cliff Swallow	5	0.81	0.01	0.25	0.05	0.02	0.01	0.02	0.17
Barn Swallow	5	1.05	0.04	0.36	0.12	0.02	0.03	0.01	0.07
Residents									
Whistling Duck (bm)	2	0.02	0.01	ND	0.01	0.01	0.01	ND	0.01
Wattled Jacana	10	0.03	0.01	ND	0.01	ND	0.01	ND	0.01
Eastern Meadowlark	10	0.04	ND	0.09	0.07	ND	ND	ND	ND

[1]Number of samples in each species pool but collected in separate areas;[2]Dichloro-diphenyl-dichloro-ethylene; [3]para-para-dichloro-diphenyl-trichloro-ethane;[4]polychlorinated biphenyls, aroclor 1254/1260; [5]Heptachlor epoxide; [6]Dieldrin; [7]endrin; [8]Alpha-hexachlorocyclohexane; [9]Beta-hexachlorocyclohexane; [10]Breast muscle; [11]Nondetectable (not included in mean), <0.005 ppm.

TABLE 2. Mean organochlorine residues in migrant and resident prey of Peregrine Falcons collected in Venezuela during fall 1986 and spring 1987 (all analyses in ppm wet weight for whole body unless indicated otherwise). Symbols as in Table 1 unless indicated.

Species	Sample Time[1]	N	DDE	P,p'-DDT	PCB	HE	Dield	End	A-HCH	B-HCH
Migrants										
Least Sandpiper	F	7	0.18	ND	0.06	0.01	0.01	ND	ND	ND
Semipalmated Sandpiper		6	0.02	ND	0.55	0.01	0.01	<0.01	ND	ND
Western Sandpiper		11	0.13	ND	0.56	ND	ND	ND	ND	ND
Sanderling		10	0.30	0.01	4.52	0.02	0.01	0.02	0.01	0.03
Lesser Yellowlegs		5	0.20	ND	0.13	0.01	0.01	<0.01	<0.01	<0.01
Solitary Sandpiper		10	1.20	ND	0.41	0.01	0.01	ND	ND	ND
Willet		5	0.13	ND	1.24	0.01	0.01	ND	<0.01	ND
Semipalmated Plover		10	0.37	ND	0.90	0.02	0.22	ND	<0.01	0.02
Ruddy Turnstone		9	0.19	ND	0.98	0.01	0.01	ND	ND	ND
Bodolink		8	0.06	ND	0.15	0.01	0.01	ND	<0.01	ND
Residents										
Tree Ducks (bm)		10	0.03	ND	0.08	ND	ND	ND	ND	ND
(liver)		10	<0.01	ND	0.02	ND	ND	ND	ND	ND
Southern Lapwing		8	1.34	0.01	0.33	0.15	0.08	0.02	<0.01	ND
Migrants										
Least Sandpiper	S	10	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Semipalmated Sandpiper		10	<0.01	<0.01	0.17	0.01	<0.01	<0.01	ND	<0.01
Sandering		10	0.06	<0.01	1.14	<0.01	<0.01	<0.01	ND	ND
Greater Yellowlegs		6	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	ND	ND
Ruddy Turnstone		10	0.03	0.01	0.95	0.01	<0.01	0.01	<0.01	<0.01
Residents										
Collared Plover		11	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Wattled Jacana		10	0.01	<0.01	0.02	<0.01	<0.01	<0.01	ND	<0.01
Eared Dove		10	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	ND	<0.01

[1]F = fall; S = following spring.

but, in the fall, the Solitary Sandpiper, *Tringa solitaria,* and the Southern Lapwing, *Vanellus chilensis,* DDE levels exceeded 1.00 ppm. DDE levels for residents, except the Lapwing in the fall, were negligible in both fall and spring.

Mexico

Analyses indicated that the mean DDE level in fall migrants (0.68 ppm, SD ± 0.47) did not differ significantly from that of spring migrants (1.12 ppm, SD ± 1.09) (Table 3). Two of eight fall migrant species, Greater Yellowlegs, *Tringa melanoleuca,* and Lesser Yellowlegs, exhibited DDE levels in excess of 1.00 ppm, the former also exceeding DeWeese et al.'s (1986) 3.00 ppm threshold. DDE levels of three of the seven spring migrants, Sanderling, *Calidris alba,* Spotted Sandpiper, *Actitis macularia,* and Barn Swallow, also exceeded 1.00 ppm. The mean DDE levels of four migrants increased from fall to spring by 1.7 to 12.5 times.

Discussion

The only mean DDE level of concern was the 1.12 ppm for spring migrants in Mexico. However, 3 of 12 fall migrant species in Panama, 1 of 10 fall migrant species in Venezuela, and 2 of 8 fall migrant species as well as 3 of 7 spring migrants in Mexico exceeded 1.00 ppm DDE. These species pools emphasize that insectivorous and carnivorous feeders exhibit higher DDE levels than omnivorous feeders (DeWeese et al. 1986; Fyfe et al. 1990). The Willet, *Catoptrophorus semipalmatus,* an aquatic insect feeder, could show more contamination than the Eastern Meadowlark, *Sturnella magna,* a terrestrial insect feeder, because aquatic insects rapidly metabolize DDT to DDE and bioaccumulate DDE to concentrations several times greater than in the water (Derr and Zabik 1972; Lindberg et al. 1985; Baril et al. 1990).

Some species collected during the fall in Panama (3), Venezuela (1), and Mexico (2) may have arrived from North America with 1.05 to 4.83 ppm DDE in their tissues or may have acquired these DDE levels after arrival on the wintering grounds (Tables 1, 2, and 3) but these levels were often lower than those found in resident and migrant birds in the United States (0.05 to 14.32 ppm) (Clark and Krynitsky

TABLE 3. Mean organochlorine residues in migrant prey of Peregrine Falcons collected in Mexico during fall 1987 and spring 1988 (all analyses in ppm wet weight for whole body unless indicated otherwise). Symbols as in Table 1 and 2.

Species	Sample Time	N	DDE	P,p'-DDT	PCB	HE	Dield	End	A-HCH	B-HCH
Migrants										
Least Sandpiper	F	11	0.05	<0.01	0.04	0.01	<0.01	<0.01	<0.01	0.01
Western Sandpiper		10	0.83	<0.01	0.53	<0.01	<0.01	<0.01	<0.01	0.01
Sanderling		9	0.49	0.02	0.79	0.02	0.01	<0.01	<0.01	0.01
Greater Yellowlegs		1	4.83	0.01	0.18	0.09	0.03	0.01	<0.01	<0.01
Lesser Sandpiper		3	1.45	0.01	0.01	0.02	0.01	0.01	<0.01	0.01
Spotted Sandpiper		7	0.24	<0.01	0.44	0.01	0.01	<0.01	<0.01	0.02
Semipalmated Plover		6	0.75	<0.01	0.40	0.07	0.01	0.01	<0.01	0.01
Barn Swallow		8	0.94	0.01	0.50	0.07	0.07	0.01	<0.01	0.01
Least Sandpiper	S	5	0.13	ND	0.06	0.07	0.06	ND	0.01	0.03
Sanderling		11	1.23	ND	0.36	ND	ND	ND	<0.01	0.01
Greater Yellowlegs		3	0.25	0.03	0.09	ND	ND	ND	<0.01	<0.01
Lesser Yellowlegs		4	0.46	ND	0.13	0.01	0.04	ND	0.01	0.04
Spotted Sandpiper		8	2.99	ND	1.40	0.02	ND	ND	<0.01	0.04
Semipalmated Plover		2	0.36	ND	0.13	0.02	0.03	ND	<0.01	0.01
Barn Swallow		6	1.63	0.05	0.36	ND	ND	ND	ND	0.01

1983; Fleming et al. 1983; DeWeese et al. 1986). Previous analysis data from fall migrants collected in Peru, Ecuador, and Costa Rica also exceeded these levels (1.09 to 5.67 ppm) (Fyfe et al. 1990). These data indicate either the continued illegal use of DDT, a precursor of DDE, or an alternate source of DDE.

DDT levels in this study ranged from 0.01 to 0.05 ppm, indicating little recent use thereof. To track down these high DDE levels exemplified by continued reproductive failures of peregrine populations in the United States, even long after DDT was banned, Hunt et al. (1986) sampled peregrine prey in California and western Texas. The majority of the Texas samples showed high DDE levels; however, low DDT levels indicated little recent use and suggested a different source of DDE. Research by Risebrough et al. (1986) concluded that technical dicofol was the source of a major portion of the high DDE levels found both in California and western Texas. Therefore the higher DDE levels in fall migrants collected in this study and by Fyfe et al. (1990) could also originate from technical dicofol.

Dieldrin levels exceeded 0.10 ppm in only two samples and give no grounds for concern. PCB levels remained below 5.00 ppm, the level above which reproduction in birds appears to be affected (Peakall 1986). The levels of A-HCH and B-HCH exceeded 0.10 ppm in only the Cliff Swallow, *Hirundo pyrrhonota* (Table 1); the significance of these organochlorines to peregrines remains unknown.

Conclusions

Our data show that peregrines migrating through or overwintering in Panama and Venezuela are not exposed to significant organochlorine contamination; however, in Mexico one-third of the migrants showed DDE levels in excess of 1.00 ppm suggesting continued adverse effects on the potential productivity of Peregrine Falcons. Fall migrants arriving in Latin America with DDE levels in excess of 1.00 ppm support the presence in North America of a DDE source other than DDT. Resident species such as the Southern Lapwing (Table 2) and an Aplomado Falcon, *Falco femoralis*, both insectivorous and carnivorous feeders (Hector 1985), and the omnivorous Great-tailed Grackle, *Cassidix mexicanus* (Banasch, unpublished data) exhibited 2.31, 1.34 ppm, and 1.56 ppm DDE but these levels pose no known threat to the reproductive success of these species.

These data indicate that future sampling should include more resident insectivores and carnivores as well as migrants to delineate areas of pesticide use. To augment these data, we require more knowledge on the foraging strategies and prey preferences of both the peregrine and its prey on the wintering grounds as well as on the breeding grounds (Peakall et al. 1990).

Acknowledgments

We thank Francisco Delgado of the University of Santiago for organizing the project in Panama and providing laboratory space for specimen preparation, and Lorenzo Delgado Junior for collecting the samples. Wilmer Villalobos collected the majority of the Venezuelan samples with assistance from Gilberto Rios of the University of the Western Llanos (UNELLEZ), Guanare. The University of Zulia in Maracaibo and the University of the Western Llanos (UNELLEZ), Guanare, provided freezers and laboratory space for sample preparation. Don Taphorn of

the University of Guanare welcomed us into his home and allowed us to work from there. We also thank Jose Lira for translating our project into understandable Venezuelan Spanish. In Mexico, Mario Ramos provided guidance and support for the project, Lilia Albert ensured that laboratory space became available at INIREB, and Ernesto Roelas helped during the spring sampling.

Back in Canada, Colleen Hyslop, C.W.S. Latin American Program Coordinator, helped direct the necessary paperwork and funding to permit the project to proceed. Both Colleen Hyslop and Steven Wendt provided needed assistance quickly when I unexpectedly phoned from Mexico. We express our appreciation for all this assistance. The staff who carried out the analyses deserve a thank-you also. All comments from reviewers were appreciated. Lastly, Sam Barry, the biostatistician, provided interpretive advice to aid in the writing up of these data.

Literature Cited

Baril, A., J.E. Elliott, J.D. Somers, and **G. Erickson.** 1990. Residue levels of environmental contaminants in prey species of the Peregrine Falcon, *Falco peregrinus*, in Canada. Canadian Field-Naturalist 104: 273–284.

Bijleveld, M. 1974. Birds of prey in Europe. MacMillan Press Ltd., London, England.

Burton, D.K., and **B.J.R. Philogene.** 1988. An overview of pesticide usage in Latin America. A report to the Canadian Wildlife Service Latin American Program. Environment Canada, Wildlife Toxicology Division, 100 Gamelin Boulevard, Hull, Quebec.

Clark, D.R. Jr., and **A.J. Krynitsky.** 1983. DDT: recent contamination in New Mexico and Arizona? Environment 25: 27–31.

Court, G.S., C.C. Gates, D.A. Boag, J.D. MacNeil, D.M. Bradley, A.C. Fesser, J.R. Patterson, G.B. Stenhouse, and **L.W. Oliphant.** 1990. A toxicological assessment of Peregrine Falcons, *Falco peregrinus tundrius*, breeding in the Keewatin District of Northwest Territories, Canada. Canadian Field-Naturalist 104: 255–272.

Derr, S.K., and **M.J. Zabik.** 1972. Biologically active compounds in the aquatic environment: the uptake and distribution of [1,1-dichloro-2, 2-bis (p-chlorophenyl) ethylene] DDE by *Chironomus tentans* Fabricius (Diptera: Chironomidae). Transactions American Fisheries Society 2: 323–329.

DeWeese, L.R., L.C. McEwen, G.L. Hensler, and **B.E. Petersen.** 1986. Organochlorine contaminants in Passeriformes and other avian prey of the Peregrine Falcon in the western United States. Environmental Toxicology and Chemistry 5: 675–693.

Encalada, M.A. 1985. Pesticides in Ecuador: beyond a simple warning. Fundacion Natura.

Enderson, J.H., G.R. Craig, W.A. Burnham, and **D.D. Berger.** 1982. Eggshell thinning and organochlorine residues in Rocky Mountain Peregrines, *Falco peregrinus,* and their prey. Canadian Field-Naturalist 96: 255–264.

Fleming, W.J., D.R. Clark Jr., and **C.J. Henny.** 1983. Organochlorine pesticides and PCBs: a continuing problem for the 1980s. Transactions of the North American Wildlife and Natural Resources Conference 48: 186–199.

Fyfe, R.W., R.W. Risebrough, and **W. Walker, II.** 1976. Pollutant effects on the reproduction of the Prairie Falcons and Merlins of the Canadian prairies. Canadian Field-Naturalist 90: 346–355.

Fyfe, R.W., U. Banasch, V. Benavides, N. Hilgert de Benavides, A. Luscombe, and **J. Sanchez.** 1990. Organochlorine residues in potential prey of Peregrine Falcons, *Falco peregrinus*, in Latin America. Canadian Field-Naturalist 104: 284–292.

Hector, D.P. The diet of the Aplomado Falcon (*Falco femoralis*) in eastern Mexico. Condor 87: 336-342.

Henny, C.J., F.P. Ward, K.E. Riddle, and **R.M. Prouty.** 1982. Migratory Peregrine Falcons, *Falco peregrinus*, accumulate pesticides in Latin America during winter. Canadian Field-Naturalist 96: 333–338.

Hunt, W.G., B.S. Johnson, C.G. Thelander, B.J. Walton, and **R.W. Risebrough.** 1986. Environmental levels of p,p'-DDE indicate multiple sources. Environmental Toxicology and Chemistry 5: 21–27.

Kiff, L.F. 1988. Changes in the status of the Peregrine in North America: an overview. Pages 123-139 *in* Peregrine Falcon populations: their management and recovery. Proceedings of the 1985 International Peregrine Conference, Sacramento. *Edited by* T.J. Cade, J.H. Enderson, C.G. Thelander, and C.M. White. Braun-Brumfeld, San Francisco.

Lindberg, P., T. Odjso, and **L. Reutergardh.** 1985. Residue levels of polychlorobiphenyls, DDT, and mercury in bird species commonly preyed upon by the Peregrine Falcon (*Falco peregrinus* Tunst.) in Sweden. Archives of Environmental Contamination and Toxicology 14: 203–212.

Newton, I. 1979. Population ecology of raptors. Berkhamstead, England. T. and A.D. Poyser, Calton.

Peakall, D.B. 1986. Accumulation and effects on birds. Pages 31-47 *in* PCBs and the Environment. Volume II. *Edited by* J.S. Waid. CRC Press, Boca Raton, Florida. 191 pages.

Peakall, D.B., and **L.F. Kiff.** 1979. Eggshell thinning and DDE residue levels among Peregrine Falcons *Falco peregrinus*: a global perspective. Ibis 121: 200–204.

Peakall, D.B., and **L.F. Kiff.** 1988. DDE contamination in Peregrines and American kestrels and its effect on reproduction. Pages 337-350 *in* Peregrine Falcon populations: their management and recovery. Proceedings of the 1985 International Peregrine Conference, Sacramento. *Edited by* T.J. Cade, J.H. Enderson, C.G. Thelander, and C.M. White. Braun-Brumfeld, San Francisco.

Peakall, D.B., T.J. Cade, C.M. White, and **J.R. Haugh.** 1975. Organochlorine residues in Alaskan peregrines. Pesticide Monitoring Journal 8: 255–260.

Peakall, D.B., D.G. Noble, J.E. Elliott, J.D. Somers, and **G. Erickson.** 1990. Environmental contaminants in Canadian Peregrine Falcons, *Falco peregrinus*: a toxicological assessment. Canadian Field-Naturalist 104: 244–254.

Ratcliffe, D.A. 1980. The Peregrine Falcon. Vermillion, South Dakota. Buteo Books.

Ratcliffe, D.A. 1984. The peregrine breeding population of the United Kingdom in 1981. Bird Study 31: 1–18.

Reynolds, L. M., and **T. Cooper.** 1975. Analysis of organochlorine residues in fish. Water Quality Parameter. American Society of Testing Materials. Special Technical Report 573: 196–205.

Risebrough, R. W. 1986. Pesticides and bird popuations. Current Ornithology 3: 397–427.

Risebrough, R. W., and **D. B. Peakall.** 1988. Commentary - the relative importance of the several organochlorines in the decline of Peregrine Falcon populations. Pages 449-462 *in* Peregrine Falcon populations: their management and recovery. Proceedings of the 1985 International Peregrine Conference, Sacramento. *Edited by* T. J. Cade, J. H. Enderson, C. G. Thelander, and C. M. White. Braun-Brumfeld, San Francisco.

Risebrough, R. W., W. M. Jarman, A. M. Springer, W. Walker II, and **W. G. Hunt.** 1986. A metabolic derivation of DDE from Kelthane. Environmental Toxicology and Chemistry 5: 13–19.

Springer, A. M., W. Walker II, R. W. Risebrough, D. Benfield, D. H. Ellis, W. G. Mattox, D. P. Mindell, and **D. G. Roseneau.** 1984. Origins of organochlorines accumulated by Peregrine Falcons, *Falco peregrinus*, breeding in Alaska and Greenland. Canadian Field-Naturalist 98: 159-166.

Received 19 February 1992
Accepted 23 April 1993

A Ten-year Urban Winter Bird Count in Sackville, New Brunswick

ANTHONY J. ERSKINE

P.O. Box 1327, Sackville, New Brunswick E0A 3C0

Erskine, Anthony J. 1992. A ten-year urban winter bird count in Sackville, New Brunswick. Canadian Field-Naturalist 106(4): 499–506.

Birds were counted in ten winters, 1977-1988 on a plot comprising part of the built-up area of Sackville, New Brunswick. Nine species were noted in six or more of the first eight winters, but most were scarcer or absent in the last two years (1986-1988). Review of possible influences on bird numbers suggested that (1) weather did not affect the trends, (2) decreasing effectiveness of the observer was not the only factor involved, and (3) human activity (urbanization) has made the town less attractive to birds.

Key Words: Bird populations, winter, urban areas, Sackville, New Brunswick.

Monitoring changes in bird numbers is one means of detecting species that may be declining, locally or generally. It also may help to identify factors responsible for observed trends. The Winter Bird Population Study (WBPS; Anonymous 1950; Robbins 1981) counts may be used for comparing winter bird communities. This technique has been used for comparing bird numbers in urban centres over series of winters (e.g., Beidleman et al. 1979), but Canadian studies using this method spanned only one or two winters for any urban (built-up) plot (*see* Erskine 1975, 1980a), the six-winter study by Dance (1989) in southern Ontario including only woodland and field habitats. The Winter Bird Population Study method provides sample counts on measured areas, not complete censuses. Standardization of these field surveys is imperfect (Robbins 1972, 1981; *see* Taylor 1991 on repeatability in biological surveys generally).

In this paper I report on a 10-winter study in Sackville, New Brunswick (45°50'N, 64°20'W; population ca. 6000), of which only the first year's data were reported earlier (Erskine 1979). Changes in the abundance indices in Sackville may help in recognizing real population changes in this region. I discuss the changes in winter birds on the Sackville plot in the context of observer effectiveness, weather during the surveys and over the study period, and alterations in the habitat, with allowance - where possible - for limitations and biases inherent in the method. I was the only observer on all surveys in all years.

Study area

The Sackville study area was described earlier (Erskine 1979, 1980b). It comprised 50 ha (ca. 125 acres), with about 10% of the street frontage vacant, and extensive vacant land, mostly as unmowed grass and forbs, in the interiors of some blocks. The built-up areas comprised ca. 80% residential, 10% commercial, and 10% other (municipal buildings, hospital and medical centre, service clubs, etc.). During the study, four small buildings were demolished, and five larger ones were built in formerly vacant areas; several trees and areas of saplings were removed. Other recent "tidying-up" included removal of most unplanned shrubbery in the northeast quarter of the plot, and planting of 20 small trees there. It also included patching of openings in run-down buildings, where European Starlings* and House Sparrows formerly nested. The original, rather general, landscape description still applies, despite these changes.

The municipal dump ca. 700 m southeast of the study area was closed and replaced by a landfill site 20 km to the north after 31 October 1983. Gulls, ravens, crows and starlings, including many sometimes seen on the plot, fed at the dump until it closed. No other commercial or industrial food sources (fast food outlets, feed-grain storage, etc.) were known on or adjoining the study area. A small farm feed-lot ca. 600 m southwest of the plot was not known to be used by birds from the town.

Although several people residing on the study area put out food for birds intermittently, only two locations, active in 1981-1986 and 1985-present, respectively, were stocked regularly with a variety of bird foods. Some unusual birds were noted at these feeders at other times, but not during any of my surveys. Neither feeding station showed consistently large numbers of birds during the surveys. Artificial feeding on the area seemed to have little direct effect on the results, but presumably it somewhat increased the overall attractiveness of the area to birds.

Methods

The plot was surveyed, using the Winter Bird Population Study procedure, each winter from 1977-1978 through 1987-1988, except in 1980-1981 when I was ill during January. Extreme dates of surveys

*Scientific names given in Table 1 and footnotes thereto.

TABLE 1. Winter bird population indices, Sackville, New Brunswick, 1977-1988[1].

Species	Mean bird count in winter of survey									
	77–78 (7)[2]	78–79 (4)	79–80 (6)	81–82 (4)	82-83 (5)	83-84 (6)	84-85 (6)	85-86 (5)	86-87 (6)	87-88 (6)
Sharp-shinned Hawk (*Accipiter striatus*)	(0.1)			[3]						
Ring-necked Pheasant (*Phasianus colchicus*)										(0.2)
Herring Gull (*Larus argentatus*)	0.4	(o'h)[4]		(o'h)	(o'h)		5 (0.2)			
Rock Dove (*Columba livia*)	3.1	7.5	7.2	1.5	4.6	5.7	7.8	8.4	11.0	13.0
Downy Woodpecker (*Picoides pubescens*)					(0.2)					
Hairy Woodpecker (*Picoides villosus*)			0.3							
Blue Jay (*Cyanocitta cristata*)	2.6	4.0	5.2	3.3	2.4	2.2	3.7	1.2	0.8	0.7
American Crow (*Corvus brachyrhynchos*)	1.0	1.5	1.3	2.5	2.4	2.2	1.5	2.0	1.7	2.0
Common Raven (*Corvus corax*)	(o'h)	(0.3)	(o'h)	(o'h)	(o'h)	(o'h)[5]		(o'h)		(o'h)
Black-capped Chickadee (*Parus atricapillus*)	0.6	(0.3)	0.3	1.0	0.4	0.7	1.1	1.6	0.5	0.7
White-breasted Nuthatch (*Sitta carolinensis*)			0.5			(0.2)				
American Robin (*Turdus migratorius*)			0.3							
Northern Mockingbird (*Mimus polyglottus*)			(0.2)							
Bohemian Waxwing (*Bombycilla garrulus*)				0.8						
European Starling (*Sturnus vulgaris*)	147.0	53.2	74.3	90.2	50.2	47.7	65.8	59.2	35.0	30.2
American Tree Sparrow (*Spizella arborea*)								(0.2)		
Common Grackle (*Quiscalus quiscala*)	1.7	(0.3)	(0.2)	0.5	1.2	(0.3)		0.6		
Brown-headed Cowbird (*Molothrus ater*)	1.3		2.7		0.6	3.2	0.3	1.6		
Pine Grosbeak (*Pinicola enucleator*)								2.6	(0.2)	
Purple Finch (*Carpodacus purpureus*)						(1.0)				
Common Redpoll (*Carduelis flammea*)				3.0				(o'h)	17.2	(o'h)
Pine Siskin (*Carduelis pinus*)									(0.7)	
American Goldfinch (*Carduelis tristis*)					(o'h)	(0.2)		(o'h)		15.0
Evening Grosbeak (*Coccothraustes vespertina*)	(0.1)	(5.0)	5.5	8.0	15.2	13.2	17.3	21.6	1.7	
House Sparrow (*Passer domesticus*)	139.3	147.8	57.3[6]	107.8	108.0	108.0	96.5	93.8	55.2	41.8
Span of survey dates[7]	19D-26F	18D-3M	1J-5M	21D-30J	30D-28F	24D-4M	29D-2M	28D-15F	30D-28F	27D-27F[8]

[1]No surveys in 1980-1981, owing to illness and adverse weather during January.
[2]Number of surveys in winter.
[3]Index number in parentheses was based on sighting(s) on only one survey in that winter.
[4](o'h) = species only seen flying over the plot in that winter.
[5]*Note*: Town dump (700m SE of plot) closed 31 October 1983.
[6]*Note*: Die-off (perhaps from *Salmonella*) in January 1980.
[7]D=December, J=January, F=February, M=March.
[8]Additional species seen in flight over the plot, but not on plot in any winter: Great Black-backed Gull (*Larus marinus*) - 77–78, 78–79, 81–82, 82-83; Snow Bunting (*Plectrophenax nivalis*) - 81–82; Red Crossbill (*Loxia curvirostra*) - 81–82.

TABLE2. Weather conditions during winter bird counts, Sackville, New Brunswick, 1977-1988.

Variable (range)		Value, or, Occurrences during winter									
		77-78 (7)[1]	78-79 (4)	79-80 (6)	[2] 81-82 (4)	82-83 (5)	83-84 (6)	84-85 (6)	85-86 (5)	86-87 (6)	87-88 (6)
Mean duration (h:m)		2:15	1:58	2:05	2:17	2:17	2:16	2:20	2:23	2:14	2:15
Range of survey hours		07:40-12:28	08:28-11:56	07:30-11:49	09:15-12:36	08:32-12:02	07:50-12:11	08:17-12:38	08:40-12:26	08:27-13:03	08:07-12:23
Sky cover (tenths):	0-1	3	1	2	2		1	1	3	2	1
	2-4		2	1		2	1	2			2
	5+	3	1	1	1	3	3	3	2	2	3
	hazy	1		2	1		1				2
Wind (Beaufort):	0-1	4	2	3	1	1	1	1	2	3	1
	2-3	3	1	3	2	2	4	5	2	2	3
	>3		1		1	2	1		1	1	2
Temperature (°C):	>=0	1				1	1	1	1	1	2
	-1 to -5	3	2	1	1	3	1	2	2	2	
	-6 to -10	1	1	4	1		2	1	2	2	2
	<-10	2	1	1	2	1	2	2		1	2
Precipitation:	Snow						2		1		2
	Rain						1				
	Drizzle	1						1			
Snow on ground:	none		1								
(cm)	<5		1		1	1	2	2	2	2	
	5-15	2	2	4		3	2				
	16-30			2	1			2	3		1
	>30	5			2	1	2	2	3	4	5

[1]Number of surveys in winter.
[2]No surveys made in 1980-1981.

were 18 December and 5 March (Table 1), thus avoiding the main migration periods (cf. Boyer 1972). In four winters, unsuitable weather, illness, or work commitments allowed me to complete only four or five surveys, instead of the six or more recommended (*compare* Robbins 1981). Surveys, all in the forenoon, and starting in full daylight (i.e., at least 30 min after sunrise) except on a few very cold mornings, averaged 2 1/4 h in duration (Table 2). The same route, traversing all streets in the area, was followed each time, with the direction reversed on alternate surveys. I did not enter back yards where birds were heard, but I attempted to view such areas from the side or rear. I avoided making surveys at temperatures below -15°C, sometimes by starting 1-2 h later. I also avoided days with sustained winds stronger than force 3 (Beaufort). I aborted counts if continuing snow or rain obviously inhibited bird vocalizations or my ability to hear them.

All birds seen or heard were noted in the field on a map of the area. When birds were seen to fly away, and the same species was seen later in the area towards which those seen earlier had flown, I assumed that the same birds were involved, and marked the map with arrows to suggest this. In some cases, birds that flew were seen to land, but more often this was only guessed. I believe that most such flights ended within the study area rather than continuing into nearby fields, except for birds going to the dump.

House Sparrows and European Starlings often occurred as pairs or small groups, but noisy "parliaments" (up to 70 starlings and 150 sparrows) sometimes assembled all these birds from several blocks into one yard or one tree. I assumed that each "parliament" included all birds of that species seen in smaller groups within 200 m of the assembly site. Blue Jays sometimes moved, calling, across the plot and back, touching at feeders enroute. Crows, ravens, and gulls were even more mobile. With such movements and assemblies, many individual birds were seen more than once on a survey. After each survey, I assessed all inferred duplicate records which might lead to overestimates, and adjusted the totals downward.

I visited known feeders, but I did not make prolonged observations there; to have done so would have increased the species list, but it would have further complicated the interpretation of numbers of starlings and House Sparrows. The mean of the adjusted counts for a species in one winter was taken as the annual index to abundance. Individual birds seen in flight over but not on the plot (marked "o'h" in Table 1 for species seen on plot in some year; others noted in footnote to Table 1) were counted during surveys but were not included in computing indices.

Weather conditions [% cloud cover, wind direction and strength (Beaufort scale), and temperature (°C)] were noted at the start and finish of each count, and the mean depth of snow cover (some areas were blown clear) was estimated. Long-term climatic data (Table 3) were obtained from the Moncton airport weather office 40 km northwest (monthly summaries, Atmospheric Environment Service, Environment Canada); Sackville temperatures averaged 1-2°C higher than in Moncton in winter (personal observations).

Results

Annual population indices are summarized in Table 1 and Figure 1 (except that cowbird is omitted in Figure 1). Rock Dove, Blue Jay, American Crow, Black-capped Chickadee, European Starling and House Sparrow were seen every year, and Evening Grosbeak was missed in only one winter. Common Grackle and Brown-headed Cowbird were seen in seven and six winters, respectively. Few Dark-eyed Juncos, *Junco hyemalis,* and American Tree Sparrows, *Spizella arborea,* were ever detected on the study area, although they wintered regularly in other parts of the town of Sackville.

Obvious changes in bird abundance (Figure 1) included:

- Rock Doves increased annually over the last six years, but only the last two years had more than in 1978-1980.
- Fewer Blue Jays were seen in the last three years than earlier.
- Crows and chickadees varied up and down with no overall pattern, but chickadees had increased generally until the last two winters.
- More starlings were seen in the first year and fewer in the last two years than in between.
- No grackles or cowbirds were seen in the last two years.
- More House Sparrows were seen in the first two years, and fewer in 1979-1980 and in the last two years, than in any others.

The most striking feature, evident in all common species except Rock Dove and American Crow, was the low counts in the last two winters, when redpolls and goldfinches were found more often than earlier. Statistical testing (Table 4) confirmed that most of the apparent overall trends arose from the scarcities in the last two years.

Discussion

Trends in the summed annual indices for all species reflected mainly the trends in the two most numerous species, House Sparrow and European Starling, which showed substantial declines without fully compensating increases (Figure 1). The larger samples obtained, by thus "combining apples and oranges" in all-species totals, might show statistically significant trends, suggesting that common factors acted on counts of most or all species - as some factors undoubtedly do. The

TABLE 3. Monthly mean temperatures (°C) and snowfall (cm) at Moncton, New Brunswick, airport weather office.

Variable	Long-term mean (1941-70; 1951-80)	Mean value in winter									
		77-78	78-79	79-80	81-82[1]	82-83	83-84	84-85	85-86	86-87	87-88
Temperature (°C)											
December	-5.3;-5.4	-4.9	-6.0	-4.8	-2.0	-2.8	-5.9	-3.8	-8.3	-5.6	-6.3
January	-7.9;-8.1	-8.8	-6.5	-8.1	-12.2	-6.7	-9.4	-11.8	-7.6	-9.4	-8.4
February	-7.6;-7.7	-9.1	-9.8	-8.9	-9.3	-7.6	-3.5	-7.1	-8.8	-9.2	-8.3
Snowfall (cm)											
December	62.5;72.1	100.6	93.1	52.4	60.8	49.9	35.6	42.3	59.7	29.9	150.7
January	73.7;77.8	133.8	65.5	26.5	142.3	36.1	111.8	53.5	116.9	152.9	45.9
February	70.4;68.4	70.4	40.9	32.3	93.2	97.5	51.9	57.7	57.5	84.0	120.1

[1]Weather data for 1980-1981 not extracted, as no surveys made that winter.

absence of any consistent pattern in the trends (Figure 1), other than the low counts in the last two years, argued that most factors affected the various species in different ways and degrees.

(a) Representativeness of the counts. Difficulties in inspecting back yards make most WBPS counts in urban areas incomplete. Previous discussion of the method mostly considered plots in eastern broad-leafed forests near the southern limits of snow cover. Many common birds there are territorial in winter, although natural foods often occur patchily. Birds in such areas may be more sedentary, and counts of them more replicable, than where they range between suburban feeders and nearby natural habitats in winter.

I had used the WBPS method in residential areas at Ottawa, Ontario, where winter birds were scarce outside the city (in comparison with densities in the built-up areas I studied), in 1969-1976, a period featuring heavy snowfalls there (Erskine 1975). Except for nomadic finches and waxwings, urban birds in Ottawa seemed to rely mainly on feeding stations. In nearby Carleton Place, a town similar in size to Sackville, bird densities indexed by the WBPS were comparable to those in Ottawa (Erskine 1974), probably because nearby rural lands lacked forest cover. Most winter birds of both town and city were restricted to built-up areas. Repeated winter surveys of the fairly sedentary birds there gave similar counts, with little evidence of duplication, and the indices they provided had predictive value for urban bird community composition (Erskine 1975, 1980a).

The survey data at Sackville were more often complicated than in Ottawa by bird movements within, and into and out of, the plot. Adjustments for possible duplication in counts could not be completely objective, although they were based on long-term knowledge of the species and of the area. I re-adjusted the survey totals from the original field sheets, and re-computed annual indices, 3-14 years after the original summaries, and obtained slightly different values in a few cases. The close similarity of most new totals to the earlier ones provides the adjustment process with some credibility, but this cannot be verified statistically.

(b) Observer. Change in an observer's effectiveness is inevitable, with aging. My eyesight worsened and my hearing deteriorated during the study period, and I used hearing aids in surveys starting in winter 1981-1982. Tests of my eyesight and hearing in 1986-88 suggested no further deterioration compared with tests in 1980-1981, but I had a growing impression of decreased ability to detect birds, which presumably contributed to lower counts in later years of the study. This impression led me to terminate the survey after the winter of 1987-1988, and no other observer was willing to continue the counts.

TABLE 4. Regressions of annual indices of winter bird abundance in Sackville, New Brunswick, 1977-1978 through 1987-1988, and 1977-1978 through 1985-1986. Key to slopes: + increase, - decrease, n.c. no change. Significance: * $P < 0.05$; n.s. not significant.

Species	Slopes through 1988	Slopes through 1986	Regressions 1977-1978 to 1987-1988	Regressions 1977-1978 to 1985-1986
Rock Dove	+	n.c.	0.684 *	0.358 n.s.
Blue Jay	–	n.c.	0.733 *	0.523 n.s.
American Crow	n.c.	n.c.	0.461 n.s.	0.573 n.s.
Black-capped Chickadee	n.c.	+	0.447 n.s.	0.739 *
European Starling	–	–	0.715 *	0.584 n.s.
Common Grackle	–	n.c.	0.556 n.s.	0.388 n.s.
Brown-headed Cowbird	n.c.	n.c.	0.216 n.s.	0.100 n.s.
Evening Grosbeak	n.c.	+	0.552 n.s.	0.970 *
House Sparrow	–	n.c.	0.690 *	0.412 n.s.

(c) Conditions during surveys. The conditions during counts (Table 2) also influenced the effectiveness of coverage. Low temperatures reduced the numbers of birds detected, because covering the ears (essential below -10°C) reduced one's ability to hear birds. Sackville's perennial wind exacerbated the effects of cold on the observer, but did not always reduce calling and other activity by birds. As in Ottawa (Erskine 1975), at -15°C starlings often clustered on warm chimneys where they were easily seen and counted. Variations in sky cover made no detectable difference to bird activity, but glare on new snow was often dazzling. Snow piles, up to 4 m high, along streets and driveways sometimes restricted what could be seen from the street. Light drizzle or snow showers had no obvious effect on bird activity, but birds did not call in rain or heavy snow. Traffic noise sometimes interfered with hearing, especially when streets were wet or in the vicinity of snow-throwers and plows.

These factors cannot be standardized, and their effects on counts have not been measured, in this or other studies. Adverse conditions probably resulted in fewer birds being detected than were present. The conditions during surveys were not consistently worse in any one year than another; snow depths on survey dates in the last two winters averaged greater than in earlier years, except 1977-1978 (Table 2), but this was not apparent in monthly snowfall totals (Table 3). I concluded that varying conditions on count days would not likely have influenced trends in my bird counts.

(d) Climate. The study period averaged a little colder and snowier than the 30-year "normal" periods (Table 3). Months with low temperatures or high snowfalls did not coincide with low bird numbers, including the generally low counts in the last two years, and conversely months with higher average temperatures and light snowfall did not show higher bird numbers (this was not tested statistically). The survey period had few extremes in climate, and recent departures from normal climatic values were within the usual range, to which bird numbers presumably are adapted. "Global warming" or other climatic trends cannot plausibly be invoked to explain the observed changes in these local bird counts.

(e) Other factors. In 1979-1980, a die-off occurred, involving two-thirds of the local House Sparrows, perhaps caused by *Salmonella* infection (Erskine 1980c). Other species were not affected. No die-offs were reported in the last two years, when low counts included several species besides House Sparrows.

After the dump closure in 1983, gulls and Common Ravens decreased around town, in the plot counts and also in the local Christmas Bird Counts (CBC), which cover a wider area. Starlings probably changed their foraging patterns after the dump closed. In 1986-1987, and again in 1988-1989, starlings often fed on bare fields outside town through January; this may explain their low index in 1986-1987, but not in the snowy winter of 1987-1988.

House Sparrow counts on the CBC did not change after the dump closed, and the major die-off of 1979-1980 also was not apparent on the next CBC; the CBC probably does not track local changes in this species reliably. Although House Sparrows nest three times in a season, my summer surveys of the same plot (Erskine 1980b, 1982) suggested that House Sparrow numbers in 1981 were one-third lower than in 1979, i.e. recovery from the January 1980 die-off was not complete after the 1980 breeding season, *or* it was cancelled by losses in winter 1980-1981 when no counts were made.

"Downtown revitalization", resulting in substantial changes to the landscape in the northeast quarter of the plot, started here about 1986, just before the last two winters of surveys when low counts of House Sparrows and European Starlings became

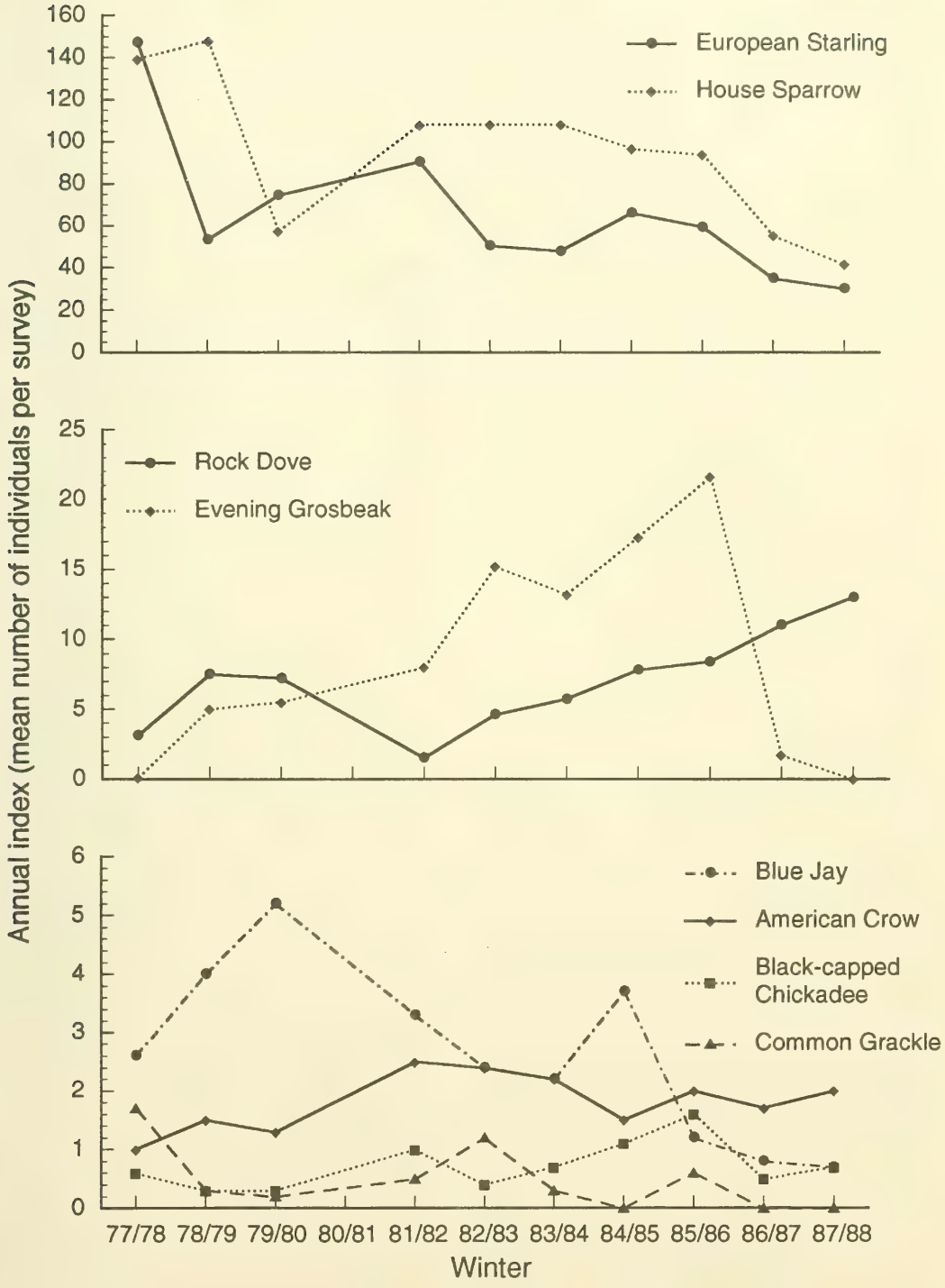


FIGURE 1. Annual indices for major species encountered in winter bird counts 1977-1988, Sackville, New Brunswick. Note different scales for three sections. No data for winter 1980-1981.

very noticeable. These species, however, were also scarcer in residential areas not affected by that program. The erection of new buildings, refurbishing of old structures, and removal of unplanned shrubbery are human efforts to "improve" our urban areas - but most people also wish to see birds around their homes. Loss of vacant lots and shrubbery reduced cover and foraging areas in centre-town, but loss of nesting/roosting sites may have been more important. As all birds are adversely affected when their nesting and resting places are eliminated, the passion for tidiness exemplified by "urban renewal" works against the desire to see wild life in Canada's towns and cities. However, unless a "threshold of tolerance" for birds was passed here, the increased urbanization probably was only one factor in the observed decrease in urban birds, as declines occurred also in unaltered parts of the plot and involved even alien species considered to be pre-adapted to cities and towns (also compare urbanization trends given by Erskine 1975, 1980a).

Blue Jay and Evening Grosbeak numbers had fluctuated in the past, and these native species were sometimes as scarce as in the final two winters. In 1964-1965 no Blue Jays were noted locally between December and April, and I saw only one Evening Grosbeak on the plot in winter 1977-1978. Blue Jays were even less often noted in town in 1988-1989 than in the two preceding winters. All of these low counts may reflect "normal variation" rather than continuing declines.

(f) Some final comments. In recent winters (up to and including 1991-1992), I received many queries on apparent scarcity of birds in Sackville and nearby Moncton. Cohrs (1989) summarized reports suggesting similar scarcity in Nova Scotia, at all seasons. My counts on the Sackville plot indicated a scarcity of several species starting about 1986, when other people in Sackville and elsewhere also found fewer birds. The lower counts were not caused solely by my declining effectiveness as an observer, as other people remarked on similar declines.

Comparisons with local weather and climate were inconclusive. Most physical and vegetational changes seemed likely to reduce the area's attractiveness to birds. None of the causes considered adequately explained the recent scarcity of winter birds in this area. Most birds that winter here breed locally or farther to the north, so we cannot blame these declines on tropical deforestation or habitat fragmentation in the United States. The causes of the changes observed must be sought in Canada rather than farther south.

Acknowledgments

I thank all the anonymous referees, for the two journals to which this article was offered, for their helpful comments.

Literature Cited

Anonymous. 1950. Instructions for making bird population studies. Audubon Field Notes 4: 183–187.

Beidleman, R., W. Gomez, J. Hanske, B. Harwood, S. Libell, J. Mealy, and **V. Pool.** 1979. Downtown business district - residential area. American Birds 33: 52.

Boyer, G. F. 1972. Birds of the Nova Scotia - New Brunswick border region. Canadian Wildlife Service Occasional Paper Number 8 (Second Edition). 46 pages.

Cohrs, S. 1989. Editorial. Nova Scotia Birds 31(2): 23–24.

Dance, K. W. 1989. Frequency of winter bird occurrence at an urban conservation area. Ontario Birds 7: 20–25.

Erskine, A. J. 1974. Urban residential area - VII. American Birds 28: 727.

Erskine, A. J. 1975. Winter birds of urban residential areas in eastern Canada. Pages 18–31 *in* Nature and Urban Man. *Edited by* G.B. McKeating. Canadian Nature Federation Special Publication Number 4.

Erskine, A. J. 1979. Small town, residential and commerical [sic] areas. American Birds 33: 52.

Erskine, A. J. 1980a. Urban birds in the context of Canadian climate and settlement. Acta Congressus Internationalis Ornithologicus 17: 1321–1326.

Erskine, A. J. 1980b. Small town, residential and commercial areas. American Birds 34: 103–104.

Erskine, A. J. 1980c. A House Sparrow die-off. Nova Scotia Bird Society Newsletter 22: 183–184.

Erskine, A. J. 1982. Small town, residential and commercial areas. American Birds 36: 106.

Robbins, C. S. 1972. An appraisal of the Winter Bird-Population Study technique. American Birds 26: 688–692.

Robbins, C. S. 1981. Reappraisal of the Winter Bird-Population Study technique. Studies in Avian Biology 6: 52–57.

Taylor, L. R. 1991. Proper studies and the Art of the Soluble. Ibis 133 (Supplement 1): 9–23.

Received 10 March 1992
Accepted 20 July 1993

Recent American Avocet, *Recurvirostra americana*, Breeding Records in the Northwest Territories, with Notes on Avocet Parasitism of Mew Gull, *Larus canus*, Nests

ERNIE KUYT[1] AND BRIAN W. JOHNS[2]

[1]Canadian Wildlife Service, Room 210, 4999 - 98 Avenue, Edmonton, Alberta T6B 2X3
[2]Canadian Wildlife Service, 115 Perimeter Road, Saskatoon, Saskatchewan S7N 0X4

Kuyt, Ernie, and Brian W. Johns. 1992. Recent American Avocet, *Recurvirostra americana*, breeding records in the Northwest Territories, with notes on avocet parasitism of Mew Gull, *Larus canus*, nests. Canadian Field-Naturalist 106(4): 507–510.

Recent breeding records of American Avocet (*Recurvirostra americana*) in the Northwest Territories and two incidences of parasitism of Mew Gull (*Larus canus*) nests are described.

Key Words: American Avocet, *Recurvirostra americana*, breeding records, nest parasitism, Northwest Territories.

In the Canadian prairie provinces, the American Avocet, *Recurvirostra americana* breeds as far north as Beaverhill Lake and Lower Thérien Lake, Alberta; Edam and Big Quill Lake, Saskatchewan; and Delta and West Shoal Lake in Manitoba (Godfrey 1986). The species formerly occurred much farther north, and specimens were taken in the nineteenth century at Rae (breeding record about 1861) and Fort Resolution, Northwest Territories (NWT) as well as near Fort Chipewyan and Lesser Slave Lake in Alberta (Godfrey 1986).

More recently, Gulley (1983) observed small numbers of avocets near Fort McMurray, northern Alberta, in spring 1977, 1980, 1981 and 1982. Kuyt (1989) on 17 May 1988 noted the first recent occurrence of American Avocet in the Fox Holes area, about 35 km westnorthwest of Fort Smith, NWT. He suggested that dry conditions in southern nesting areas could account for the recent northern occurrence of prairie nesting birds such as the American Avocet and Wilson's Phalarope, *Phalaropus tricolor*, (Kuyt 1974; Pankratz and Kuyt 1986).

Observations

On 21 May 1989, Kuyt revisited a small island in the shallow (estimated as 0.6 – 0.8 m deep) lake in the Fox Holes area where in 1988 he had seen a pair of avocets. From a distance he saw two avocets, one resting on its breast. The bird soon stood up, and with its bill appeared to move some objects near its feet. It then sat down, rotating from side to side. This oft-repeated behaviour resembled that described by Gibson (1971) as avocet nest construction. Some time later, a Golden Eagle, *Aquila chrysaetos*, flew past the island and disturbed the avocets, which flew to the north shore of the lake. Kuyt then examined the island and found a shallow nest scrape in a small tuft of sedge, *Carex* sp. The nest cup contained a few short pieces of dry grass or sedge but no eggs. Several metres away were the nest and three eggs of a Mew Gull, *Larus canus*. The previous year Kuyt found two Mew Gull nests on the island (Prairie Nest Records Scheme, Manitoba Museum of Man and Nature, Winnipeg).

On 22 May 1989, Kuyt, from a low-flying aircraft, saw two avocets near the nest on the small island, but on 26 May during another ground visit the nest cup was no longer identifiable, although one adult avocet was observed in the area.

In 1990, because of an arthritic knee, Kuyt was unable to make ground visits to the Fox Holes. During a flight to the Whooping Crane, *Grus americana*, breeding range on 27 May he saw eight avocets in the vicinity of the same shallow pond. Two birds were on the island near the previous year's nest scrape.

On 20 May 1991 both authors visited the area and counted 47 American Avocets on or near the shallow lake. From the air on 24 and 28 May we saw many avocets and several Mew Gulls on the small island. One avocet and two Mew Gulls appeared to be on nests. On 30 May we found six avocet nests and two Mew Gull nests on the island. Only 24 avocets were noted in the vicinity, so half of the avocets seen 10 days earlier had moved elsewhere. Some of these birds may have flown even farther north, as on 15 June during an aerial survey we flushed three American Avocets from the shore of a large shallow lake at 60° 20'N, 112° 53'W. This lake is 38 km northwest of the nest island, but still within the extensive alluvial lowlands between the Little Buffalo and Slave Rivers. This flat, often marshy, terrain contains numerous wetlands and may become an avenue of travel for American Avocets and other shorebirds extending their range to the south shore of Great Slave Lake.

FIGURE 1. Avocet nest island, Fox Holes, Northwest Territories.

The Fox Holes avocet nest island, shaped somewhat like a large question mark, is about 115 m long and only 6 m across at its widest part (Figure 1). Much of the island is less than 15 cm above the lake surface and would be largely flooded during periods of strong wave action.

The vegetation of the island and its shoreline consisted of a few grass-like species such as *Carex aquatilis, C. limosa, Scirpus* sp., and *Eleocharis* sp.. On somewhat firmer ground near nests we noted luxurious growth of Arrow-grass, *Triglochin maritima* and Silverweed, *Potentilla anserina*.

Because of the narrow shape of the island, all nests were close to water. Five avocet nests averaged 28 cm from the island's edge, while one nest was 200 cm from the edge. Average nest diameter was 18 cm. Avocet nests were found in low grass and sedge hummocks (two nests) or on marshy ground (four nests). All nests had soggy bottoms. Nest material consisted of dead sedge or grass stalks, and amount of material varied from sparse (in incomplete clutches) to extensive (in clutches of four and six eggs). The six avocet nests contained 2 eggs (two nests), 3 eggs, 4 eggs (two nests) and 6 eggs. One nest was located 8 m from a Mew Gull nest. This Mew Gull nest and a second one measured respectively 25 and 30 cm across, were conspicuously located on grassy hummocks, contained large amounts of dry grass and were dry on the bottom. These nests contained two and three Mew Gull eggs as well as a single avocet egg each. The smaller size of avocet eggs (50 x 35 mm, Harrison 1984), their pear shape and greenish ground colour (as opposed to olive in the gull eggs) readily distinguished them from the larger (57 x 41 mm, Bent 1921) and more ovate Mew Gull eggs (Figure 2). We did not measure eggs in the superclutch of six eggs (Figure 3); all eggs appeared similar in size, shape and colour. Gibson (1971) noticed two different egg sizes in dump nests, suggesting that two females had laid eggs in the same nest. Kondla and Pinel (1978) found that different females laid eggs not only in a 6-egg clutch but also in 4- or 5-egg clutches.

We did not determine stage of incubation of eggs, but earlier observations suggested that the two species had initiated laying activities about the same time. Incubation periods for American Avocet (22–24 days) and Mew Gull (22–27 days) are similar (Harrison 1984).

Discussion

Breeding of American Avocets at the Fox Holes is of recent occurrence. Kuyt visited the Fox Holes frequently in spring and summer each year for almost 30 seasons. Many Fort Smith birdwatchers and waterfowl hunters frequent the wetlands there. If avocets had been in the area prior to 1988, they undoubtedly would have been reported. First nesting of the species on an island agrees with Giroux (1985) that avocets tend to nest in association with other pairs and prefer nesting on islands, particularly those with short plant cover. These preferences may relate to the relative safety from terrestrial

FIGURE 2. Mew Gull nest with gull eggs and single avocet egg, Fox Holes, Northwest Territories.

FIGURE 3. Avocet superclutch, Fox Holes, Northwest Territories.

predators and a group defence directed towards avian or other predators (Giroux 1985; Gibson 1971).

Many authors have reported egg dumping (facultative intraspecific parasitism, Payne 1977) and occurrence of superclutches (Bent 1927; Gibson 1971; Vermeer 1971; Giroux 1985). Kondla and Pinel (1978), summarizing published and unpublished data, Giroux (1985) and other authors found four eggs to be the modal clutch in American Avocets, as in most other shorebirds. Clutches containing 7 or 8 eggs are not unusual. Kondla and Pinel (1978) even reported a clutch of 10 eggs. The occurrence of superclutches appears greatest in the northern parts of the avocet breeding range, and these large clutches are often associated with island nest situations (Giroux 1985). Gibson (1971) found a much greater hatching success in avocet nests containing 3 or 4 eggs than those with 2 or 8 eggs. In 8-egg clutches the eggs were probably not turned properly by the incubating bird whose incubation patch was unlikely to be large enough to cover all eggs. The intraspecific egg dumping by American Avocets requires a violation of territory (Gibson 1971), but how this behaviour occurs was not observed.

In contrast to the not unusual occurrence of superclutches in American Avocets, interspecific nest parasitism in this species is rare. Vermeer (1971) and Stewart (1975) reported nests containing eggs of avocets and Common Tern *Sterna hirundo* in the same nest. In both locations, the two species were nesting together on bare sandbars and it was uncertain whether avocet eggs were in tern nests or *vice versa*. In the Fox Holes, the nests in which the mixed clutches were found were clearly Mew Gull nests (large dry nests, large amounts of nest material, nests attended by Mew Gulls) and the gulls had accepted the avocet eggs.

During Alberta waterfowl studies, B. Turner and P. Pryor (Canadian Wildlife Service, personal communications) found lower nest success in parasitized and large clutches than in normal clutches. Most parasitic birds are altricial and seldom are their eggs smaller than those of the host (Payne 1977). In the avocet-Mew Gull examples, the reverse is true. Avocets do not feed their young and it would have been interesting to observe hatching of mixed clutches and determine whether avocet chicks remained with "foster" parents or joined nearby avocet families.

With avocets commonly producing superclutches and laying some eggs in nests of other species, there would have to be an advantage of this behaviour to avocets. Payne (1977) discussed some advantages and suggested that, given the prevalence of single-egg nest parasitism, brood parasitism may be an evolutionary "strategy" to spread the risks of predation.

Literature Cited

Bent, A. C. 1921. Life histories of North American gulls and terns. United States National Museum Bulletin 113. 345 pages.

Bent, A. C. 1927. Life histories of North American shorebirds Part 2. United States National Museum Bulletin 142. 412 pages.

Gibson, F. 1971. The breeding biology of the American Avocet (*Recurvirostra americana*) in Central Oregon. Condor 73: 444–454.

Giroux, J-F. 1985. Nest sites and superclutches of American avocets on artificial islands. Canadian Journal of Zoology 63: 1302–1305.

Godfrey, W. E. 1986. The birds of Canada. National Museums of Canada. 595 pages.

Gulley, J. R. 1983. Unusual avian observations for the Fort McMurray, Alberta area, 1976-1982. Alberta Naturalist 13(2): 45–47.

Harrison, C. 1984. A field guide to the nests, eggs and nestlings of North American birds. Collins Publishers, Don Mills, Ontario. 416 pages.

Kondla, N. G. and **H. W. Pinel**. 1978. Clutch size of the American Avocet in the prairie provinces. Blue Jay 36(3): 150–153.

Kuyt, E. 1974. Wilson's phalarope in breeding plumage near Fort Smith, NWT. Blue Jay 32(3): 177–178.

Kuyt, E. 1989. A recent record of American avocet in the Northwest Territories. Alberta Naturalist 19(1): 27–29.

Pankratz, H. and **E. Kuyt**. 1986. Occurrence in northern Alberta of Wilson's phalarope and first breeding record for the NWT. Alberta Naturalist 16(1): 9–10.

Payne, R. B. 1977. The ecology of brood parasitism in birds. Annual Review of Ecology and Systematics 8: 1–28.

Stewart, R. E. 1975. Breeding birds of North Dakota. Tri-College Center for Environmental Studies. Fargo, North Dakota. 295 pages.

Vermeer, K. 1971. Large American Avocet clutches at Dowling Lake, Alberta. Blue Jay 29(1): 88.

Received 12 March 1992
Accepted 14 July 1993

Notes

First Record of the Rough-legged Hawk, *Buteo lagopus,* from Ellesmere Island, Northwest Territories

R. France and M. Sharp

Department of Biology McGill University, 1205 Ave. Dr. Penfield, Montreal, Quebec H3A 1B1

France, R., and M. Sharp. 1992. First record of the Rough-legged Hawk, *Buteo lagopus,* from Ellesmere Island, Northwest Territories. Canadian Field-Naturalist 106(4): 511–512.

A Rough-legged Hawk (*Buteo lagopus*) was observed on two separate occasions over a small localized area at the head of Makinson Inlet on southeastern Ellesmere Island. This is the most northerly record for this species and a first for Ellesmere Island.

Key Words: Rough-legged Hawk, *Buteo lagopus,* Ellesmere Island, Northwest Territories, northern record.

Only three diurnal raptors are thought to breed within the archipelago of the Canadian Arctic: the Gyrfalcon (*Falco rusticolus)*, Peregrine Falcon (*Falco peregrinus*), and Rough-legged Hawk (*Buteo lagopus*). Knowledge of the last's distribution is incomplete (Bray 1943; Porsild 1951; Sutton and Parmelee 1956; Fraser 1957; Godfrey 1966, 1986). Rough-legged Hawks have been recorded from neither Greenland (Sutton and Parmelee 1956; Burnham and Mattox 1984), nor the Canadian islands of the High Arctic - Devon, Cornwallis, Ellef Ringnes, Amund Ringnes, and Axel Heiberg (Godfrey 1986; Pattie 1990). Similarly, this species had not been documented from Ellesmere Island (Fielden 1877; Greeley 1886; MacMillan 1918; Soper 1940; MacDonald 1953; Godfrey 1953; Parmelee and MacDonald 1960; Williams 1980), despite detailed lists being produced there for several discrete "oases" known to be favorable habitats for avifauna (Savile and Oliver 1964; Nettleship and Mahr 1973; Freedman and Svoboda 1982; Schlederman 1980; Gould 1988).

While undertaking a ski-traverse of Ellesmere Island (*see* France and Sharp 1992a,b, 1993; France 1992, 1993) our expedition identified a single adult Rough-legged Hawk (in pale phase) at the head of Makinson Inlet which bisects the icefields of the southeastern corner of the island. At 77° 40' N, this sighting extends the northern distribution of the Rough-legged Hawk in the eastern High Arctic by about 500 km.

The hawk was observed circling the same localized area on two separate occasions during 16 and 17 June 1990, suggesting it was not engaged in a rapid fly through but was at least a temporary resident. The Makinson Inlet region is very remote, not being fully explored until the 1930s (Haig-Thomas 1939). The particular location in which the hawk was observed is an area of about 100 km^2, being bounded to the east by the Prince of Wales Icefield rising to a height of 1300 m, and to the north and south by the Split Lake and Hook Glaciers which descend to sea level (Vendom Fiord Map 1:250 000 49D). This region surrounds a large lake and is separated from the coast on the west by a range of hills exceeding 300 m. Located only 10 km away over the still frozen sea ice of late June, is the seldom observed Makinson Polynya (Sadler 1974; France and Sharp 1992b). In comparison with the encircling polar desert, the enclosed putative "oasis" (France and Sharp 1993) contains a particularly diverse and productive early spring avian community including Snow Buntings, Baird's Sandpipers, Red Knots, Ruddy Turnstones, Rock Ptarmigan, Parasitic and Long-tailed Jaegers, and Common Ringed Plovers. Although a pair of Snowy Owls was observed nesting at the site, the duration of occupation by the solitary Rough-legged Hawk is unknown.

Acknowledgments

The Arctic Light Expedition was sponsored by the World Wildlife Fund Canada and the Royal Canadian Geographical Society and was organized by J. Dunn and G. Magor. Expedition support was provided by (among others) Asnes, Mountain Equipment Co-op, Chorophylle, J. Ingle Insurance, Calgary Herald, Bolle, Paris Gloves, Coll-tex, Stillongs, Harvest Foodworks, Kauffman Footwear, MSR, North Face, Lowe, Leki, C.E. Jamieson and the Canadian Himalayan Fund, Calgary.

Literature Cited

Bray, R. 1943. Notes on the birds of Southampton Island, Baffin Island and Melville Penninsula. Auk 60:504–536.

Burnham, W. A. and **W. G. Mattox.** 1984. Biology of the peregrine and gyrfalcon in Greenland. Meddelel serom Gronland, Bioscience 14. 25 pages.

Fielden, H. W. 1877. List of birds observed in Smith Sound and the Polar Basin, during the Arctic Expedition of 1875-1876. Ibis 1: 401–412.

France, R. L. 1992. Aerial mobbing of a Gyrfalcon by Glaucous Gulls. Journal of Raptor Research 26(4): 269.

France, R. L. 1993. The Lake Hazen Trough: a late-winter oasis in a polar desert. Biological Conservation 0163: 149–151.

France, R. L., and **M. Sharp**. 1992a. Newly reported colonies of Ivory gulls on Ellesmere Island. Arctic 45: 306–307.

France, R. L., and **M. Sharp.** 1992b. Polynyas as centres of organization for structuring the integrity of Arctic marine communities. Conservation Biology 6: 442–446.

France, R. L., and **M. Sharp.** 1993. Comparison of avian species richness and abundance for localized oases on Ellesmere Island. Polarfushcung 61: 147–152.

Fraser, J. K. 1957. Birds observed in the central Canadian Arctic, 1953, 1955, 1956. Canadian Field-Naturalist 71: 192–199.

Freedman, B., and **J. Svoboda.** 1982. Populations of breeding birds at Alexandra Ford, Ellesmere Island, Northwest Territories, compared with other Arctic localities. Canadian Field Naturalist 96: 56–60.

Godfrey, W. E. 1953. Notes on Ellesmere Island birds. Canadian Field-Naturalist 67: 89–93.

Godfrey, W. E. 1966. The birds of Canada. National Museum of Natural Science. 428 pages.

Godfrey, W. E. 1986. The birds of Canada. Revised edition. National Museum of Natural Science. 595 pages.

Gould, J. 1988. A comparison of avian and mammalian fauna at Lake Hazen, Northwest Territories, in 1961-62 and 1981-82. Canadian Field Naturalist 102: 666–670.

Greely, A. W. 1886. Three Years of Arctic Service. An account of the Lady Franklin Bay Expedition of 1881-84 and the attainment of the farthest north. Volume I; 428 pages Volume II 444 pages. Scribner's, New York.

Haig-Thomas, D. 1939. Tracks in the Snow. Hodder and Stroughten. London. 292 pages.

MacDonald, S. D. 1953. Report of biological investigations at Alert, N.W.T. National Museum Canadian Bulletin 128: 241–256.

MacMillan, D. B. 1918. Four Years in the White North. Harper and Brothers Publishers, New York. 426 pages.

Nettleship, D. N., and **W. J. Mahr.** 1973. The avifauna of Hazen Camp, Ellesmere Island, N.W.T. Polarforschung 44: 66–74.

Parmelee, D. F., and **S. D. MacDonald.** 1960. The birds of westcentral Ellesmere Island and adjacent areas. National Museum Canadian Bulletin 169.

Pattie, D. L. 1990. A 16-year record of summer birds on Truelove Lowland, Devon Island, Northwest Territories, Canada. Arctic 43: 275–283.

Porsild, A. E. 1951. Bird notes from Banks and Victoria islands. Canadian Field-Naturalist 65: 40-42.

Sadler, H. E. 1974. On a polynya in Makinson Inlet. Arctic 27: 157–159.

Savile, D. B. O., and **D. R. Oliver.** 1964. Bird and mammal observations at Hazen Camp, northern Ellesmere Island. Canadian Field-Naturalist 78: 1–7.

Schlederman, P. 1980. Polynya and prehistoric settlement patterns. Arctic 33: 292-302.

Soper, J. D. 1940. Local distribution of eastern Canadian arctic birds. Auk 57: 13–21.

Sutton, G. M., and **D. F. Parmelee.** 1956. The rough-legged hawk in the American Arctic. Arctic 9: 202–208.

Williams, S. R. 1980. The report of the Joint Services Expedition to Princess Marie Bay, Ellesmere Island. Defence Research Board U.K., London. 234 pages.

Received 3 December 1990
Accepted 25 February 1993

Swim by an Arctic Fox, *Alopex lagopus*, in Alexandra Fiord, Ellesmere Island, Northwest Territories

HAROLD STRUB

1010-5300 49th Street, Yellowknife, Northwest Territories X1A 3G5

Strub, Harold. 1992. Swim by an Arctic Fox, *Alopex lagopus*, in Alexandra Fiord, Ellesmere Island, Northwest Territories. Canadian Field–Naturalist 106(4): 513–514.

An Arctic Fox (*Alopex lagopus*) was observed to interrupt a 2.1 kilometer swim by resting in the sun on an ice floe, Alexandra Fiord, eastern Ellesmere Island in mid-July 1990.

Key Words: Arctic Fox, *Alopex lagopus*, swim, sea water.

The Arctic Fox, *Alopex lagopus*, swims readily (Banfield 1977; Murie 1959) but observations of long swims have not been reported in detail. Dementyeff (1958) stated that Arctic Foxes have been seen swimming as much as 2 km across the rivers, bays and inlets of the mainland abutting the Kara Sea. In southwestern Alaska, Murie (1959) reported Arctic Foxes swimming short distances between islands, hunting salmon in water and even seizing ducks below water as they rise from a dive.

On the night of 18 July 1990, an Arctic Fox was observed swimming a long distance through sea water at Alexandra Fiord, Ellesmere Island, Northwest Territories (78°55'N, 75°45'W). Although the first "quarter" of the swim was not observed, the least distance between a possible starting point, a prominent, sphinx-like island in the middle of the fiord west of Skraeling Island, and the observed landing point at the main delta of the Twin Glacier River on the south side of the fiord scales 2.1 km on Canadian Hydrographic Service Chart 7371 (1:25 000). A least-distance course would mean swimming from the north-northwest to the south-southeast. The observed track appeared to have a stronger west-east component however, putting candidate points of departure on any of several skerries west of "Sphinx Island". The least distance between a skerry and the delta is about 2.4 km. The three "quarters" of the course actually observed followed a straight line and the fox may have used a prominent bluff 1.5 km behind the delta as a homing beacon as suggested by Dementyeff (1958).

About half way along its course to the river delta the fox climbed out of the water onto the only ice floe in sight, a thin slab about 4 m long by 3 m wide. Judging from its silhouette, the fox assumed the sternal position, head erect, forelegs facing the sun, its back toward the observation point on the south shore of the fiord.

Fifteen minutes later the fox stood up, walked three paces to the east edge of the floe, hesitated for half a second with head down, and slipped into the water to resume its swim. The fox swam strongly for about fifteen minutes during the third "quarter" of its journey to the mainland but slowed appreciably in the last "quarter". At all times the fox rode high in the water presenting an unbroken silhouette above the surface from head to end of tail, as noted by Banfield (1977). It climbed out among the stones and boulders of the delta where only its lateral running movements could be detected with binoculars against the low-contrast background.

Excluding the stop on the ice floe, total observed swimming time was about 45 minutes. In the hours around solar midnight when the swim occurred the sky was clear to the north, the surface of the fiord was 95% ice-free (fast ice present), dead calm and flooded with sunlight. It was high tide, slack water. Water temperature was estimated to be +1°C and air temperature +6°C.

The Arctic Fox's excellent tolerance for low temperatures and food scarcity in winter, due chiefly to the insulative properties of thick fur and subcutaneous fat, are well documented (Prestrud 1991; Korhonen et al. 1985). Fur thickness and fat content vary seasonally however and are at the minimum in summer (Prestrud 1991). The Arctic Fox observed here spent at least 55 minutes in the near-freezing sea water. The stop on the ice floe, apparently for the purpose of resting in the sun, may indicate that Arctic Fox fur is more susceptible to wetting and consequent drop in thermal resistance than the fur of habitual swimmers such as caribou and polar bear.

Acknowledgments

This observation was made in the course of an unrelated project assisted by the Arctic Awareness Program of the Polar Continental Shelf Project. I am indebted to fellow-observer Julie Desrosiers for a literature search and to Anne Gunn for a review of the first draft.

Literature Cited

Banfield, A. W. F. 1977. Mammals of Canada. University of Toronto Press. 438 pages.

Dementyeff, N. I. 1958. Biology of the Arctic Fox in the Bolshezemelskaya Tundra. Canadian Wildlife Service: Translations of Russian Game Reports 3: 166–181.

Korhonen, H., M. Harri and **E. Hohtola.** 1985. Response to cold in the Blue Fox and Raccoon Dog as evaluated by metabolism, heart rate and muscular shivering: A re-evaluation. Comparative Biochemistry and Physiology 82A(4): 959–964.

Murie, O. J. 1959. Fauna of the Aleutian Islands and Alaska Peninsula. North American Fauna 61, U.S. Fish and Wildlife Service. 405 pages.

Pretrud, P. 1991. Adaptations by the Arctic Fox (*Alopex lagopus*) to the polar winter. Arctic 44(2): 132–138.

Received 11 July 1991
Accepted 21 March 1993

Possible Simultaneous Rearing of Consecutive Litters by Black Bears, *Ursus americanus*.

RANDOLPH J. SEGUIN

Saskatchewan Environment and Resource Management, Box 580, Meadow Lake, Saskatchewan S0M 1V0

Seguin, Randolph J. 1992. Possible simultaneous rearing of consecutive litters by Black Bears, *Ursus americanus*. Canadian Field-Naturalist 106(4): 514–516.

Observations of female Black Bears (*Ursus americanus*) are described which suggest that they are capable of rearing consecutive year litters simultaneously. These observations are considered in relation to other observational reports on cub rearing in Black and Brown (*Ursus arctos*) bears.

Key Words: Black Bears, *Ursus americanus*, simultaneous cub rearing, Saskatchewan.

The Black Bear (*Ursus americanus*) has a reproductive strategy that typically involves spring-summer fertilization of the ovum (Jonkel and Cowan 1971; Reynolds and Beecham 1980; LeCount 1983), delayed implantation of the blastocyst in late fall (Wimsatt 1963), and parturition during the winter (Alt 1983) of alternate years (Jonkel and Cowan 1971; Reynolds and Beecham 1980; LeCount 1983). That pattern of alternate-year reproduction can be disrupted by death of newborn cubs before the end of the breeding season, or temporary cessation of lactation (which normally inhibits estrus) leading to breeding and birthing during the subsequent year (Jonkel and Cowan 1971; LeCount 1983). Alternately, an interbirth interval of more than two years can occur if the female is in a poor physiological state (Jonkel and Cowan 1971; Reynolds and Beecham 1980; Rogers 1987).

LeCount (1983) reported instances of Black Bears breeding while raising newborn cubs. He observed two female bears with newborn cubs through summer and fall until they denned. The following year the females emerged with another set of newborn cubs apparently having abandoned the young of the previous year. LeCount (1983) noted that this could be a successful reproductive strategy by allowing females to produce more young in their lifetimes.

Further, it has been mathematically demonstrated by Tait (1980) that if a female bear has a high expectation of producing two or three cubs the next year then abandonment of a single cub could be a successful reproductive strategy. As litters of two or three cubs are common in Black Bears throughout most of their range (Kolenosky and Strathearn 1987), they meet this mathematical assumption.

In this report, I present three observations that suggest wild female Black Bears reproduced in consecutive years and attempted to raise both litters simultaneously.

The first report I received, from a Regional Forester, was that of a yearling bear at a hunter's bait station on 28 April 1988. This yearling, when standing erect, was visually estimated to be approximately 100 cm (40 in) tall and weighed about 15–17 kg (40 lbs). A noise alerted the observer to a movement in a tree that held three cubs-of-the-year. Subsequently, he observed a large black phase female leading away a second yearling of approximately the same size and weight as the animal first seen. This female repeatedly returned, vocalized, and individually led away each newborn cub from the tree. Lastly she returned to the hunter's bait and left with the first yearling. The group, now consisting of the female, two yearlings, and three cubs, then moved off and disappeared from view. The reporter was extremely confident that only one female was involved as she was constantly in sight and all the bears left as a single group.

The second sighting occurred on 27 April 1989, at a garbage dump site some 14 km SE of the first sighting. At that time I observed two yearlings (both about 15 kg in weight and 90 cm [=30 lbs and 35 inches] in length) digging in a pile of refuse. Within a minute I observed a large black phase female at the end of the

clearing. It approached the yearlings, vocalized, and the yearlings responded by trotting to it. The female and two yearlings walked to approximately the location where she was first seen. The female then returned to the refuse pile, moved just past the spot where the two yearlings had been digging, crossed over another debris mound, and returned momentarily with a single newborn cub at heel. They moved toward the forest edge, and were joined by the two yearlings before exiting the clearing.

A third indication of this phenomenon was obtained from a hunter-harvested female bear (6 May 1989). In this instance a hunter (J. Reich, personal communication) reported he had shot a female bear that was attended by two yearlings. He described these yearlings as about 100 cm (40 in) in length and 18 kg (40+ lbs) in weight. While skinning the bear, the hunter did not observe any additional offspring in the vicinity. He subsequently turned in a first premolar tooth and the reproductive tract from the female in response to a general request for biological samples

From these samples, it was determined that this female was 10 years old (cementum annuli analysis by Matson's Laboratory, Montana) and that the reproductive tract had two placental scars from the previous year (confirmed by the two observed yearlings) and one scar from the year of harvest. She potentially had given birth that year. However, no newborn cub-of-the-year was noted by the hunter. The potential cub may have been aborted, died postnatally, or simply was not observed by the hunter.

The possibility exists that the two female-yearling-cub group sightings were the result of adoption. Adoption of young bears has occurred under both artificial and natural circumstances. Some success was achieved when Black Bear cubs were experimentally introduced into similarly aged litters early in the spring (Alt and Beecham 1984; Rogers 1986). By late April, however, female bears in Pennsylvania and Idaho will not accept ophans if they can identify them by smell (Alt and Beecham 1984).

Erickson and Miller (1963) describe a successful natural adoption in Brown Bears (*Ursus arctos gyas*) that occurred in late July at the McNeil River, Alaska. It was speculated that during the period of cub mixing, the identifying scents of the non-familial cubs may have been partially masked. This would have impaired the female's olfactory powers and therefore she would have been unable to distinguish her own cubs (Erickson and Miller 1963).

Instances of adoption under natural conditions appear unlikely (Erickson and Miller 1963). A successful adoption would be even less likely when cubs of different age classes are involved. Adoption would not, however, explain the third situation involving placental scars of consecutive years of origin.

For young of consecutive years to be accompanying a single female, a specific set of behavioural, physiological, and environmental factors would have to exist. Behaviourally for example, the female must temporarily abandon her cubs, seek out and accept a mate, breed and reassociate with her cubs.

Physiologically, the female also must produce mature follicles while raising her first litter. As bears are induced ovulators (Erickson and Nellor 1964), those mature follicles must be ready to rupture and release an egg for fertilization at the time of copulation. Subsequently implantation and blastocyst development must be initiated.

Environmentally, adequate nutrition must be available particularly in the fall. The link between food availability and reproduction as reported by Rogers (1976) illustrates that access to supplemental foods allows females to mature earlier, produce larger litters, and reduce the interbirth interval. The reported observations were made in west-central Saskatchewan at the interface of a provincial forest and mixed agricultural lands. Bears there have access to abundant supplemental foods such as hunter-set baits in both spring and fall (often Beaver, *Castor canadensis*, and cattle, *Bos taurus*, carcasses), bee-yards, cattle (primarily through calf/heifer depredations), grains such as fall oats, and numerous refuse dumps.

Availability of those supplemental foods may allow a female to attain the minimum body reserves required (Rogers 1976) for follicle maturation, blastocyst implantation and fetal development despite raising newborn cubs. Foods the following spring would have to be sufficient for the female to nurse new young, a major energy drain (Alt and Beecham 1984). Raising of the newborns would also have to be accomplished while caring for her yearlings through this period of negative energy balance (Kolenosky and Strathearn 1987).

The observations published by (1) LeCount (1983) of females breeding while rearing cubs, (2) Beck (1991) of a female giving birth while denned with her young of the previous year, (3) Coy and Garshelis (1992) of isolating tooth cementum layers indicative of consecutive years of reproduction and cub rearing (although not directly observed during their study period) and, (4) this report of observed mixed age litters, suggest that these conditions do occur from time to time. Some females may indeed be utilizing a set of unusual circumstances to adopt a strategy that maximizes their reproductive fitness by reproducing in consecutive years in combination with extended maternal care.

That strategy of consecutive birth years combined with extended maternal care would hold an evolutionary advantage over both alternate year and abandonment strategies, if the probability of survival of a cub-of-the-year in a mixed age litter exceeded the survival probability of an abandoned cub. That strat-

egy also would require that the ability of the female to reproduce the next year not be impeded should the younger cub(s) be lost. Indeed, the paucity of observations of mixed age litters could be due to the premature death of the cub(s)-of-the-year resulting from the usual "rough and tumble play" with older, larger, stronger siblings.

Acknowledgments

I thank F. Wilson, Forester, Saskatchewan Environment and Resource Management, Meadow Lake, Saskatchewan, for reporting his observations. Thanks go to Peter Flood and technician Maria Arts, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, for their efforts in analysing the reproductive tract. I also thank Anne C. Seguin, Instructor, Integrated Resource Management Program, Meadow Lake Tribal Council, Meadow Lake, Saskatchewan, for her assistance in developing this manuscript. Thanks go to the reviewers for their insights into this topic.

Literature Cited

Alt, G. L. 1983. Timing of parturition of black bears (*Ursus americanus*) in northeastern Pennsylvania. Journal of Mammalogy 64: 305–307.

Alt, G. L., and **J. J. Beecham.** 1984. Reintroduction of orphaned black bear cubs into the wild. Wildlife Society Bulletin 12: 169–174.

Beck, T. D. I. 1991. Black bears of west-central Colorado. Technical Publication Number 39. Colorado Division of Wildlife. Fort Collins, Colorado. 86 pages.

Coy, P. L., and **D. L. Garshelis.** 1992. Reconstructing reproductive histories of black bears from the incremental layering in dental cementum. Canadian Journal of Zoology 70: 2150–2160.

Erickson, A. W., and **L. H. Miller.** 1963. Cub adoption in the brown bear. Journal of Mammalogy 44: 584–585.

Erickson, A. W., and **J. E. Nellor.** 1964. Breeding biology of the black bear. Pages 1–45 *in* The Black Bear in Michigan. Michigan State University Agricultural Experimental Station Research Bulletin 4.

Jonkel, C. J., and **I. McT. Cowan.** 1971. The black bear in the spruce-fir forest. Wildlife Monograph Number 27. 57 pages.

Kolenosky, G. B., and **S. M. Strathearn.** 1987. Black Bear. Pages 443–454 *in* Wild Furbearer Management and Conservation in North America. *Edited by* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch. Ontario Trappers Association, North Bay, Ontario. 1150 pages.

LeCount, A. L. 1983. Evidence of wild black bears breeding while raising cubs. Journal of Wildlife Management 47: 260–268.

Reynolds, D. G., and **J. J. Beecham.** 1980. Home range activities and reproduction of black bears in west-central Idaho. International Conference on Bear Research and Management 4: 181–190.

Rogers, L. L. 1976. Effects of mast and berry crop failures on survival growth, and reproductive success of black bears. Transactions of the North American Wildlife and Natural Resources Conference 41: 431–438.

Rogers, L.L. 1986. Long-term surival of adopted black bear cubs in suboptimal habitat. Wildlife Society Bulletin 14: 81–83.

Rogers, L. L. 1987. Effects of food supply and kinship on social behaviour, movements, and population growth of black bears in northeastern Minnesota. Wildlife Monotraphy Number 97. 72 pages.

Tait, D. E. N. 1980. Abandonment as a reproductive tactic — the example of grizzly bears. American Naturalist 115: 800–808.

Wimsatt, W. A. 1963. Delayed implantation in the Ursidae, with particular reference to the black bear (*Ursus americanus Pallas*). Pages 77–98 *in* Delayed Implantation. *Edited by* A. C. Enders. University of Chicago Press, Chicago, Illinois. 316 pages.

Received 30 September 1991
Accepted 30 March 1993

Metabolism and Behavior of Wintering Common Map Turtles, *Graptemys geographica*, in Vermont

TERRY E. GRAHAM[1,2] AND ANDREW A. GRAHAM[2]

[1]Department of Biology, Worcester State College, Worcester, Massachusetts 01602
[2]Wetlands & Wildlife Associates, 209 Pommagussett Road, Rutland, Massachusetts 01543

Graham, Terry E., and Andrew A. Graham. 1992. Metabolism and behavior of wintering Common Map Turtles, *Graptemys geographica,* in Vermont. Canadian Field-Naturalist 106(4): 517–519.

Aquatic oxygen consumption, $\dot{V}O_2$ ($\mu l\ O_2 \bullet g^{-1} \bullet h^{-1}$), of three adult (2 females, 1 male) Common Map Turtles wintering on the bottom of the Lamoille River was F_1(mass = 1964 g) = 0.493; F_2(1834 g) = 0.577; and M_1(188 g) = 1.376. The higher metabolism of the male (2.4-2.8X greater than that of the females) is partly explained on the basis of the greater locomotor activity of the male than either female in the respirometer chambers. SCUBA observation of numerous map turtles on the river bottom revealed that the intersexual differences in activity level noted for animals in the chambers is similar to that of free-ranging turtles.

Key Words: Common Map Turtle, *Graptemys geographica*, aquatic gas exchange, hibernation, winter behavior, Vermont.

Northern nearctic freshwater turtles normally experience forced submergence by ice cover during winter, and must therefore rely on extrapulmonary means of respiration, such as cloacal, cutaneous, or buccopharyngeal exchange (Jackson 1979). The ability of these animals to survive is primarily due to: (1) their reduced need for O_2 because of depressed metabolism at very low ambient temperatures, and (2) their remarkable ability to exchange O_2 and CO_2 with the water (Seymour 1982). While some species burrow in soft underwater substrates, others avoid such behavior and instead lay fully exposed on the bottom, in a posture presumably much more conducive to aquatic gas exchange (Ultsch 1989). Still other species may burrow and periodically emerge into open water to avoid the severe physiological stress of prolonged burial in anoxic mud (Ultsch and Jackson 1982).

While extrapulmonary respiration was previously suggested to be an important survival mechanism for wintering emydid turtles, only studies done in the last decade have looked at aquatic gas exchange in turtles at low temperatures (Graham and Forsberg 1991). Furthermore, only one published study (Graham and Forsberg 1991) has measured gas exchange of turtles wintering *in situ*. Such studies are needed to quantify the capacity of wintering turtles for aquatic gas exchange and how it relates to their behavior in nature. The present study reports underwater observations on wintering Common Map Turtles, *Graptemys geographica*, together with measurement of their aquatic O_2 uptake determined on the river bottom at 2 °C.

Graptemys geographica were selected for study because they have been reported to hibernate without burrowing (Evermann and Clark 1916) and to walk around or rest on the bottom after the surface freezes (Newman 1906). Vogt (1980) mentioned that all three species of map turtles in Wisconsin (*G. geographica, G. ouachitensis, and G. pseudogeographica*) overwinter communally by lodging themselves in submerged rock piles behind wing dams in the sloughs and channels of the Mississippi River. At such sites they move around because commercial fishermen catch them in gill nets set beneath the ice. Evermann and Clark (1916) claimed that *G. geographica* wintering in Indiana keep walking about on the lake bottom where they can be seen through the ice all winter long. While diving at our study site in November 1989, we saw many *G. geographica* walking about on the river bottom at 6°C (unpublished observation). The reported mobility of *Graptemys* at very low temperatures suggests that their metabolic rate may be higher than that reported for other hibernating emydids (Graham and Forsberg 1991); one purpose of our research was to investigate this suggestion.

The present study was conducted in the Lamoille River, Colchester, Chittenden County, Vermont (44°36'15"N; 73°12'45"W), from 15 -18 November 1991. Following SCUBA observation of a large wintering assemblage of *G. geographica*, we transferred three adults underwater from their winter resting sites on the river bottom at 2°C to plexiglass respiration chambers (15.9-20.4 liters) which were then sealed and placed on the river bottom at 1 m depth. During the transfer turtles were not removed from the water and they were all handled quickly and as briefly as possible to minimize any potential upset to their behavior. Oxygen concentration within all three chambers was simultaneously monitored for 59 hours to determine extrapulmonary oxygen consumption (Graham and Forsberg 1991).

Oxygen consumption ($\dot{V}O_2$) for the male map turtle was 2.4 - 2.8X greater than that of the females (Table 1). It is our contention that this higher metabolic rate resulted partly from the

noticeably greater locomotor activity of the male in the respiration chamber. Although they did move occasionally, both females were considerably more sluggish than the male and spent the majority of their time sitting motionless. Our initial SCUBA observations of numerous (>100) adult *Graptemys* on the river bottom indicates that the intersexual activity differences we observed for turtles in the respiration chambers were similar to those of free-ranging animals. Males on the river bottom were moving much more frequently than females and were often found walking steadily both in proximity to stationary females and at distances of >50 m from them. Many females lay motionless beside, under, or on top of the few scattered submerged logs and rocks, while others were stationary on open sand/gravel substrates. Males moved among the females, but did not display any courtship or mating behavior. When we approached males closely in the river they usually moved away more deliberately and steadily than females did. Most females did not try to escape, although a few made feeble attempts to do so. Why the males were so active is unclear, but it is possible that their higher metabolic rate delays the onset of greater torpidity which they may experience as winter deepens.

We found the majority of map turtles congregated in a 6.7 m depression in the river bottom. The base of this oval depression was estimated to be 60 m long x 30 m wide. The river was 70-75 m wide at this point but the depression was located about 10 m from the south bank, not at midstream. J. Bonin (personal communication) performed extensive bathymetry on the Lamoille River in the vicinity of our study and for roughly 2.2 km downstream to Lake Champlain in October 1991. He indicated that the hollow where we found nearly all of the turtles represents the deepest spot in the lower section of the river. The bottom at the study site was typical of the river as a whole, with patches of sand and gravel comprising the substrate. The current 1 m below the surface was 0.1 m/s but on the bottom it was practically nil. During our previous dive in November 1989, when we noted map turtles moving on the river bottom at 6°C, relatively few of them were in the hollow, but were instead moving down slope from the south bank of the river towards the hollow.

TABLE 1. Aquatic oxygen consumption by three adult Common Map Turtles wintering on the bottom of the Lamoille River at 2°C. All $\dot{V}O_2$ values are given in $\mu l\ O_2 \cdot g^{-1} \cdot h^{-1}$. CL = Carapace Length.

Sex	Mass (g)	CL (mm)	Turtle Vol. (L)	$\dot{V}O_2$
Female	1964	244	1.895	0.493
Female	1834	241	1.720	0.577
Male	188	119	0.201	1.376

This suggests that as water temperature continues to drop the map turtles begin to move and eventually congregate in the hollow by the time the water has reached 2°C. It is possible that they seek this depression to avoid the threat of bottom-scouring by moving ice during the spring thaw. Later, by the time T_w reaches 11-13°C most map turtles have dispersed from this site.

The adult female map turtles had roughly equivalent rates of oxygen uptake at 2°C and were very similar to those of subadult Wood Turtles, *Clemmys insculpta*, at 5°C. However, the $\dot{V}O_2$ for our male map turtle was roughly 2-3X greater than that of subadult (435-488 g) Wood Turtles (Graham and Forsberg 1991). All wintering Wood Turtles typically remained almost motionless on the stream bottom and stayed for several weeks within a 6-8 m^2 area. About half of our observed differences in metabolic rate between the sexes can be accounted for by the much smaller size of the male (Gordon Ultsch, personal communication). This conclusion resulted from mathematical scaling of our females down to male size, but the intersexual differences are still real after scaling and our field observations definitely support our conclusions.

Subsequent to this study we made a trip to observe and videograph the wintering map turtles on 16 February 1992. No turtles were seen above the 4.6 m isobath under 45 cm of ice at $T_w = 0°C$. At the bottom DO = 8.3 mg/L; PO_2 = 103 mm Hg and it was pitch black. When startled by the diver's lights, males moved about more than females. Females were seen more densely packed together than males and were piled on top of one another in many instances. Nearly all turtles were sleeping with their heads and legs extended but no courtship or mating was noted. No hatchlings or small juveniles were found among this hibernating congregation and no other species were seen in the area.

Acknowledgments

The oxygen meter, electrodes, and one respirometer chamber were purchased with funds obtained from WSC minigrants; the other respirometer chamber was a gift from Bob Gatten. Wetlands & Wildlife Associates provided travel support for this work. We are grateful to Chris Fichtel and Steve Parren of the Vermont Fish and Wildlife Department for their assistance in obtaining the scientific collection permit that authorized this project. Thanks also to Joel Bonin, Derek DeLutis, and Stephane Poulin of the St. Lawrence Valley Natural History Society, who joined us on in November 1991 during our second dive. Experienced ice divers Don Flynn and Ray Schmidt of Central Scuba, Inc, Worcester, Massachusetts, are applauded for their heroic efforts during the February 1992 dive. The assistance of Paul Metcalf during that dive is gratefully acknowl-

edged, as is the critical review of an early draft of this manuscript by Gordon Ultsch.

Literature Cited

Evermann, B. W., and **H. W. Clark.** 1916. The turtles and batrachians of the Lake Maxinkuckee region. Proceedings of the Indiana Academy of Sciences 1916: 472–518.

Graham, T. E., and **J. E. Forsberg.** 1991. Aquatic oxygen uptake by naturally wintering wood turtles, *Clemmys insculpta*. Copeia 1991(3): 836–838.

Jackson, D. C. 1979. Respiration, Pages 165-191 *in* Turtles: perspectives and research. *Edited by* M. Harless and H. Morlock. John Wiley & Sons, New York.

Newman, H. H. 1906. The habits of certain tortoises. Journal of Comparative Neurology and Psychology 16: 126–152.

Seymour, R. S. 1982. Physiological adaptations to aquatic life, Pages 1-51 *in* Biology of the Reptilia, Volume 13, Physiology D, Physiological Ecology. *Edited by* C. Gans and F. H. Pough. Academic Press, New York.

Ultsch, G. R. 1989. Ecology and physiology of hibernation and overwintering among freshwater fishes, turtles, and snakes. Biological Reviews 64: 435–516.

Ultsch, G. R., and **D. C. Jackson.** 1982. Long-term submergence at 3°C of the turtle, *Chrysemys picta belli*, in normoxic and severely hypoxic water. I. Survival, gas exchange and acid-base status. Journal of Experimental Biology 96: 11–28.

Vogt, R. C. 1980. Natural history of the map turtles *Graptemys pseudogeographica* and *G. ouachitensis* in Wisconsin. Tulane Studies in Zoology and Botany 22(1): 17–48.

Received 10 January 1992
Accepted 3 March 1993

Use of a Summit Mating Area by a Pair of Courting Grizzly Bears, *Ursus arctos,* in Waterton Lakes National Park, Alberta

KEITH S. BRADY[1] AND DAVID HAMER[2]

[1]Canadian Parks Service, Waterton Lakes National Park, Waterton Park, Alberta T0K 2M0
[2]Northern Lights College, Box 1000, Fort St. John, British Columbia V1J 6K1

Brady, Keith S., and David Hamer. 1992. Use of a summit mating area by a pair of courting Grizzly Bears, *Ursus arctos*, in Waterton Lakes National Park, Alberta. Canadian Field-Naturalist 106(4): 519–520.

A pair of courting Grizzly (Brown) Bears (*Ursus arctos*) was observed on an upper-elevation summit ridge and adjacent slopes for a 12-day period, 1-12 June 1990. The male actively "herded" the female by remaining below her and displacing her upslope when she descended. Over half of this upper-elevation mating area was above the elevation known to be Grizzly Bear feeding habitat. Isolation of courting Grizzly Bears in upper-elevation, unproductive habitat, previously reported only from Banff National Park, may occur more commonly in the Rocky Mountains.

Key Words: Grizzly Bear, *Ursus arctos*, courtship, mating, herding, behaviour, Waterton Lakes National Park, Alberta.

Use of isolated, upper-elevation "mating areas" where male Grizzly Bears "herd" females, block their descent, and thus apparently sequester them in unproductive habitat was reported for five of six observations of courting pairs in Banff National Park (Herrero and Hamer 1977; Hamer and Herrero 1990). Hamer and Herrero (1990) stated that to their knowledge, "confinement to a summit or ridge during grizzly bear courtship has not been reported elsewhere in North America." We here report the use of a high-elevation mating area by a pair of courting Grizzly Bears in Waterton Lakes National Park during 1-12 June 1990.

The mating area was approximately 20 ha on the summit ridge and northeast-facing slopes of an isolated, 2380-m elevation mountain running approximately 4 km northwest-southeast, and located in the centre of the park. A ridge at 1580 m elevation connects this mountain and the neighbouring mountains to the northwest. The remaining three sides of the mountain are bordered by valley-bottom streams and lakes at 1280 - 1500 m elevation.

The mating area was alpine and avalanche meadow vegetation, with approximately 6 ha of open Alpine Larch (*Larix lyallii*) forest just below the summit ridge. The lower limits of the mating area, in avalanche meadow, contained Yellow Hedysarum (*Hedysarum sulphurescens*) and tall-forb meadow feeding habitat (Hamer, Herrero, and Brady 1991). Most of the mating area, however, was above 2100 m elevation and thus was not known feeding habitat: <1% of the Grizzly Bear feeding activity documented by Hamer, Herrero, and Brady (1991 and unpublished data) occurred above 2100 m. In addition, the

mating area was approximately 30% snow-covered at the time of these observations.

The mating pair was observed on 1 June 1990 by a park visitor. K.S.B. subsequently made observations, usually twice daily, from distances in excess of 1.5 km, using a spotting scope (15-45x). Tracks in snow provided additional information on the bears' activity.

The bears first were seen approximately 300 m below the summit ridge in Yellow Hedysarum and green vegetation feeding areas. The bears fed in this site. Tracks in snow showed prior activity at higher elevations. For the last eight days of the observation period, the pair was seen at higher elevations, often on the summit ridge. The male typically was below the female, and commonly was seen herding the female by orienting laterally to her and gradually displacing her upslope.

The female apparently tried to escape from the male on two occasions. In the first observation, the pair was within 50 m of the summit ridge. The female broke from the male and ran quickly downslope in snow, jumping, lunging, and sliding down the fall-line. The male ran after her, finally intercepting and blocking her descent; he then began to slowly herd her back upslope. In the second observation, the female moved slowly across the slope near the summit, with the male paralleling her but as much as 100 m below. The female turned abruptly and ran quickly downslope in the opposite direction for approximately 50 m. The male ran below her and commenced to displace her upslope.

The bears were not seen after 12 June, although on 14 June the tracks of two bears were seen on the northwest-facing slopes of the mountain approximately 1 km from the mating area.

The behaviour of this pair, the characteristics of the mating area, the assumed duration of confinement to the mating area, and the period of reduced food intake were comparable to the 14-day mating observation reported by Herrero and Hamer (1977) for their study area 250 km northwest of Waterton Lakes. These authors interpreted the mating behaviour as male sequestering of a female Grizzly Bear by the male and female-testing of male vigour. Our observations from Waterton Lakes National Park extend reports of this behaviour and suggest that confinement to upper-elevation mating areas by courting Grizzly Bears may be more widespread in the southern Canadian Rocky Mountains.

Acknowledgments

We thank Ron Shade for reporting the initial sighting of the mating pair.

Literature Cited

Hamer, D., and **S. Herrero.** 1990. Courtship and use of mating areas by Grizzly Bears in the Front Ranges of Banff National Park, Alberta. Canadian Journal of Zoology 68: 2695–2697.

Hamer, D., S. Herrero, and **K.S. Brady**. 1991. Food and habitat used by Grizzly Bears, *Ursus arctos*, along the continental divide in Waterton Lakes National Park, Alberta. Canadian Field-Naturalist 105: 325–329.

Herrero, S., and **D. Hamer.** 1977. Courtship and copulation of a pair of Grizzly Bears, with comments on reproductive plasticity and strategy. Journal of Mammalogy 58: 441–444.

Received 30 September 1991
Accepted 5 March 1993

Great Blue Herons, *Ardea herodias*, Feeding at a Fishing Vessel Offshore in Lake Erie

PETER J. EWINS AND BENNETT HENNESSEY

Canadian Wildlife Service - Ontario Region, Environment Canada, Canada Centre for Inland Waters, 867 Lakeshore Road, P.O. Box 5050, Burlington, Ontario L7R 4A6

Ewins, Peter J., and Bennett Hennessey 1992. Great Blue Herons, *Ardea herodias*, feeding at a fishing vessel offshore in Lake Erie. Canadian Field-Naturalist 106(4): 521–522.

Three Great Blue Herons were seen feeding on fish 15 km from the shoreline of Lake Erie, in the vicinity of a fishing vessel hauling its nets. These birds swooped down and picked up fish from near the water surface, in the manner described previously for some heron species as "dipping". Our observations constitute the first published account for the species of this foraging method and of foraging in association with a fishing vessel in open water.

Key Words: Great Blue Heron, *Ardea herodias*, foraging, open water, fishing vessel, Lake Erie.

It has long been known that wading birds (herons, storks, ibises and spoonbills) exhibit a wide range of foraging techniques (Cramp and Simmons 1977; Kushlan 1978). In 12 species of North American herons, Kushlan (1976) cited 28 different feeding behaviours, with eight of these noted in the Great Blue Heron (*Ardea herodias*). Feeding in deep water is relatively uncommon in herons, but a few different foraging techniques have been documented. The two main methods, involving the heron merely retrieving a prey item in its bill without entering the water, are "hovering" and "dipping" (Taverner 1922; Dickinson 1947; Meyerriecks 1960; Kushlan 1976), whereas "plunging", "diving", "feet first diving" and "swimming feeding" all involve the heron becoming immersed to some extent in the water (Kushlan 1976). The "dipping" behaviour has been noted for only five species of heron (Kushlan 1976, 1978), usually at high concentrations of floating or stunned prey (J. A. Kushlan, personal communication). In this paper we provide the first published account of Great Blue Herons foraging (a) by the "dipping" method, and (b) in association with a fishing vessel in open water.

On 11 June 1990 we observed three adult-plumaged Great Blue Herons feeding with a flock of c. 30 Herring Gulls (*Larus argentatus*) over water approximately 12 m deep, in the vicinity of a small commercial fishing vessel in the western basin of Lake Erie, near 41°52'N 82°48'W, about 15 km SW of Kingsville, Ontario. The herons wheeled slowly with the gulls around the stern of the boat, mostly at a height of about 10 m above the water, and on three occasions we saw a heron fly down rapidly to the water surface, pick up a fish in the bill, and fly off. We estimated these fish to be about 20 cm long, but we did not know whether they were live, stunned or dead when taken. On two of three occasions the heron was immediately harassed by gulls (attempting to steal the fish), but managed to swallow the fish as it flew away. On no occasion did a heron alight on the water. At this stage, the fishing boat was almost stationary and appeared to be starting to haul in its nets, and so some fish may have been forced to the surface (possibly stunned or disoriented) and thus more readily available to surface-feeding birds. Apparently no fish had been discarded by the fishermen by the time of our observations.

The nearest heronry in 1990, on East Sister Island about 10 km SW of the site of our observations, supported several hundred nests of Great Blue Heron, Great Egret (*Casmerodius albus*) and Black-crowned Night-Heron (*Nycticorax nycticorax*) (D.V. Weseloch, personal observation). Many of these herons foraged along mainland shorelines at least 20 km to the north, and we saw both Great Blue Herons and Great Egrets regularly making this journey during daylight hours. Although we saw no Great Egrets in the vicinity of fishing vessels on 11 June, later that day we saw two individuals flying back towards the breeding colony, midway from the mainland foraging areas; both birds were harassed by Herring Gulls until one disgorged a bolus of fish.

As these relatively shallow, productive waters in the western basin of Lake Erie still support a small commercial fishery (Rathke and McRae 1989; personal observations), some Great Blue Herons likely capitalise on this ephemeral source of fish which they encounter during flights between the breeding colony and the main foraging areas. Although smaller herons will sometimes adopt this "dipping" technique when flying over open water, perhaps when shoals of small fish are forced to the surface by predatory fish (e.g., Dickinson 1947), this opportunistic feeding behaviour may be energy-efficient for Great Blue Herons only when prey fish are relatively large and readily captured.

Acknowledgments

We are grateful to Larry Benner and the Technical Operations Section of the Research Support Division, National Water Research Institute at the Canada Centre for Inland Waters, for logistical support, and to R.W. Butler, J.A. Kushlan and D.V. Weseloh for constructive comments.

Literature Cited

Cramp, S. and **K.E.L. Simmons.** 1977. Birds of the Western Palearctic Volume I. Oxford University Press.

Dickinson, J.C. 1947. Unusual feeding habits of certain herons. Auk 64: 306–307.

Kushlan, J.A. 1976. Feeding behaviour of North American Herons. Auk 93: 86–94.

Kushlan, J. A. 1978. Feeding ecology of wading birds Pages 249-297 *in* Wading Birds. *Edited by* A. Sprunt, IV, J.C. Ogden, and S. Winckler. National Audubon Society Research Report Number 7. New York.

Meyerriecks, A.J. 1960. Comparative breeding behavior of four species of North American herons. Publications of the Nuttall Ornithological Club, Number 2.

Rathke, D.E. and **G. McRae.** 1989. 1987 Report on Great Lakes Water Quality. International Joint Commission: Windsor, Ontario.

Taverner, P.A. 1922. An aquatic habit of the Great Blue Heron. Canadian Field-Naturalist 36: 59–60.

Received 16 October 1991
Accepted 16 March 1993

Co-operative Fishing by Double-crested Cormorants, *Phalacrocorax auritus*

EDWARD V. GLANVILLE

Department of Anthropology, McMaster University, Hamilton, Ontario, L8S 4L9

Glanville, Edward V. 1992. Co-operative fishing by Double-crested Cormorants, *Phalacrocorax auritus*. Canadian Field-Naturalist 106 (4): 522–523.

A pattern of co-operative fishing in lines is described among cormorants living along the north shore of Georgian Bay, Ontario. Such co-operation depends on a sufficient density of birds, as well as suitable terrain, and seems to occur largely in late summer after the young have left the nest and suggests an increased intake of perch and other in-shore fish at this time. Doubt is therefore cast on the extrapolation of feeding data obtained through the usual process of regurgitation at the nesting sites.

Key Words: Double-crested Cormorant, *Phalacrocorax auritus*, behaviour, co-operative fishing, diet.

The Double-crested Cormorant (*Phalacrocorax auritus*) of Canada's Great Lakes can often be observed fishing in large numbers at so-called "perch holes" or other areas rich in food, in an apparent "free-for-all" of independent activity. The present report describes more organized behaviour in which 50 to 175 birds may co-operate together to drive fish into a confined area. This behaviour was observed along the North shore of Georgian Bay, between Killarney and the mouth of the French River, where the land is fragmented into a multitude of islands and bays. Some of these bays comprise long parallel-sided inlets from 50 to 150 meters across and over 200 m in length. I have repeatedly observed large flocks of cormorants assemble at the mouth of such bays as dawn breaks, the birds having flown from the roosting islands to the south. These cormorants then spread out across the inlet, forming a narrow ribbon or arc from shore to shore. They then proceed up the inlet in a commotion of splashing wings, dipping and diving, in a line of astonishing regularity, to the head of the bay where a frenzy of feeding takes place. Apart from the splashing, which can be heard for a considerable distance, the cormorants themselves are silent but their progress is followed from above by flocks of screaming gulls. Called "crow-ducks" or more disparagingly, "shit-crows" by the local fishermen, cormorants have suffered persecution in this area and are extremely wary of humans. I have only observed such co-operative behaviour in less frequented bays when no boats are about and then only in the early morning. As far as I have been able to determine, co-operative fishing is confined to the late summer and early fall when large numbers of adults and juveniles congregate together. The present observations were made from blinds on shore and no systematic attempt was made to observe birds fishing in open waters.

Co-operative fishing in extended lines was observed as long ago as 1903 in the Mexican or Neotropic Cormorant (*P. olivaceus*) when feeding in fresh water streams (Nelson 1903) but it seems to be rare or absent in most other species such as the European Great (*P. carbo*), Brandt's (*P. penicilla-*

tus), the Pelagic (*P. pelagicus*) or Red-faced (*P. urile*) cormorants (Palmer 1962). However, co-operative fishing has been described previously for the Double-crested Cormorants of San Francisco Bay in a fascinating paper by Bartholomew (1942). By late summer, large numbers of birds have collected in this area, congregating on the open water in rafts of up to 1900 birds. They then fished independently or formed long lines up to 100 yards. in length and several birds deep, apparently in pursuit of shoals of fish. Unfortunately, Bartholomew does not state at what time of year his observations were. The birds involved in co-operative activities seem to have been non-nesting as the only dates mentioned are in October and November and the birds are said to have congregated from roosts on power lines.

More recent accounts of Double-crested fishing behaviour (such as those of Palmer 1962 and Nelson 1979) rely heavily on Bartholomew, but it is worth noting that classic reports of cormorant behaviour on the Great Lakes and the St. Lawrence (Bent 1922; Lewis 1929; Taverner 1915) make no mention of co-operative fishing, nor does Mendall (1936) in his account of cormorant behaviour in Maine. High population density is necessary for the expression of this trait and its emergence on Georgian Bay may be a modern phenomenon, associated with the rapid increase of this species in recent years (Craven and Lev 1987; Hobson et al. 1989; Ludwig 1984).

The increase in numbers of cormorants on the Great Lakes has become a concern of commercial and sports fishermen and attempts have been made to establish the type and quantity of fish consumed. This research has relied heavily on the relative ease of catching cormorants at their nest sites, combined with their tendency to regurgitate recently ingested food when handled or frightened. Such studies have generally exonerated cormorants, as they have shown that non-commercial fish generally comprise the major part of the diet. For example, Ludwig et al. 1989, have shown that Alewives (*Alosa pseudoharengus*) and other non-sport fish form 76% to 79% of the biomass consumed in American waters of Lake Michigan and Lake Huron, and 44% in the North Channel and Georgian Bay on the Canadian side. On the other hand, sport and commercial fish such as Yellow Perch (*Perca flavescens*), Bass (*Micropterus dolomieui*), Trout (*Salvelinus namaycush*), Sucker (*Catostomus commersoni*), Smelt (*Osmerus mordax*) and Whitefish (*Coregonus clupeaformis*), made up only 21% to 24% and 56%, respectively (Ludwig et al. 1989, Table 2)

These and comparable data from others were collected at the nesting sites from May to early August. If, however, cooperative fishing in bays increases significantly in the later part of the year, as my data suggest, then this may result in a greater proportion of in-shore fish such as perch being taken and casts doubt on the legitimacy of extrapolating information gathered at nesting sites to other times of year.

Literature Cited

Bartholomew, G. A. 1942. The fishing activities of Double-crested Cormorants on San Francisco Bay. The Condor 44: 13–21.

Bent, A. C. 1922. Life histories of North American petrels and pelicans and their allies. United States National Museum, Smithsonian Institution, Bulletin 121. (Reprinted by Dover Pubublications, New York. 1964)

Craven, S. R., and **E. Lev.** 1987. Double-crested Cormorants in the Apostle Islands, Wisconsin, USA: Population trends, food habits, and fishery depredations. Colonial Waterbirds 10: 64–71.

Hobson, K. A., R. W. Knapton, and **W. Lysack.** 1989. Population, diet and reproductive success of Double-crested Cormorants breeding on Lake Winnipegosis, Manitoba, in 1987. Colonial Waterbirds 12: 191–197.

Lewis, H. F. 1929. The Natural History of the Double-crested Cormorant (*Phalacrocorax auritus auritus*). Ph.D. thesis, Cornell University, New York.

Ludwig , J. P. 1984. Decline, resurgence and population dynamics of Michigan and Great Lakes Double-crested Cormorants. The Jack-Pine Warbler 62: 91–102.

Ludwig, J. P., C. N. Hull, M. E. Ludwig, and **H. J. Auman.** 1989. Food habits and feeding ecology of nesting Double-crested Cormorants in the upper Great Lakes, 1986-1989. The Jack-Pine Warbler 67(4): 118–130.

Mendall, H. L. 1936. The home-life and Economic Status of the Double-crested Cormorant, *Phalacrocorax auritus auritus.* The Maine Bulletin 39 (3), University of Maine Studies, Second Series, Number 38.

Palmer, R. S. *Editor* 1962. Handbook of North American Birds, Volume 1. Yale University Press, New Haven.

Taverner, P. A. 1915. The Double-crested Cormorant (*Phalacrocorax auritus*) and its relation to the salmon industries on the Gulf of St. Lawrence. Canadian Department of Mines, Geological Survey, Museum Bulletin Number 13 (Biological Series Number 5).

Nelson, B. 1979. Seabirds; their biology and ecology. A and W Publishers Inc., New York.

Nelson, E. W. 1903. Notes on the Mexican Cormorant. The Condor 5: 139.

Received 19 December 1991
Accepted 23 March 1993

An Adult Cougar, *Felis concolor*, Killed by Gray Wolves, *Canis lupus*, in Glacier National Park, Montana

DIANE K. BOYD[1] AND GRAHAM K. NEALE[2]

Wolf Ecology Project, School of Forestry, University of Montana, Missoula, Montana 59812
[1]Mailing address: Trail Creek, Polebridge, Montana 59928
[2]Mailing address: P.O. Box 8683, Missoula, Montana 59807

Boyd, Diane K., and Graham K. Neale. 1992. An adult Cougar, *Felis concolor*, killed by Gray Wolves, *Canis lupus*, in Glacier National Park, Montana. Canadian Field-Naturalist 106(4): 524–525.

An adult female Cougar (*Felis concolor*) was killed by a pack of eight Wolves (*Canis lupus*) in Glacier National Park, Montana. Tracks indicated the Wolves treed the Cougar and killed it when it came down. They did not feed on the carcass.

Key Words: Gray Wolf, *Canis lupus*, Cougar, *Felis concolor*, Glacier National Park, Montana.

Fatal encounters have been documented in the literature between Wolves (*Canis lupus*) and Cougars (*Felis concolor*) (Schmidt and Gunson 1985; White and Boyd 1989); Wolves and Coyotes (*Canis latrans*) (Carbyn 1982; Fuller and Keith 1981; and Paquet 1991); Wolves and Black Bears (*Ursus americanus*) (Paquet and Carbyn 1986; Rogers and Mech 1981); Wolves and Fox (*Vulpes vulpes*) (Allen 1979; Mech 1970); Wolves and Wolverines (*Gulo gulo*) (Burkholder 1962); and Coyotes and Cougars (Boyd and O'Gara 1985). Killing techniques in fatal predator-predator interactions may differ from those observed during predator-prey situations. This may be due to the inherent nature of a more prolonged interaction when two predators fight, often resulting in more numerous wounds and some post-mortem trauma. Intercarnivore predation is not necessarily motivated by food attainment, as the carcasses of carnivore-killed carnivores are often not consumed by the surviving predator.

Gray Wolves and Cougars share prey and habitat along the western boundary of Glacier National Park, Montana. Direct interactions between these species are probably uncommon, and fatal encounters presumably rare. White and Boyd (1989) presented a literature review of wolf-cougar interactions and described how Gray Wolves killed and consumed a Cougar kitten in Glacier National Park. We currently report on an adult Cougar killed by the same pack of Wolves four years later, 2.3 km south of the site where the kitten was killed.

On 8 December 1990, we aerially observed a radio-collared pack of eight Wolves tugging on the intact carcass of a Cougar in the snow-covered Anaconda Creek drainage of Glacier National Park. One black Wolf was observed urinating on the Cougar's head.

On 12 December, we examined the Cougar carcass at the kill site. Fresh Grizzly Bear (*Ursus arctos*), tracks were observed 4 m from the carcass, apparently approaching it but not feeding on it. No new snow had fallen since the observations of 8 December, and tracking conditions in the snow were excellent. Tracks indicated the Wolves had treed the Cougar in a 23-cm dbh, 10-m tall, dead, nearly branchless Lodgepole Pine (*Pinus contorta*). Broken, finger-diameter branches and pieces of dead bark were scattered around the base of the tree on top of the snow. The tree trunk had a series of fresh, long scratch marks where the Cougar had clawed the trunk. Branches and bark were scraped off the tree to a height of 4 m. Larger, more suitable climbing trees were available 20 m from the treed Cougar; therefore, we presumed the Cougar was surprised suddenly by the Wolves and climbed the nearest, rather than the safest, tree.

It appeared that the Wolves had trapped the Cougar in the dead tree, the Cougar could not hold its grip on the branchless, small-diameter tree, and was forced to descend into the pack of waiting Wolves. The Wolves and Cougar struggled on the ground in an area 4 m across before the Cougar was killed. The Wolves dragged the dead Cougar 15 m downslope and abandoned the carcass at the edge of a wet seep. The female Cougar was not lactating at the time of her death, and was estimated to be 3-4 years old (M. Johnson, personal communication).

The Wolves did not feed on the Cougar, but 10% of the carcass had been consumed by scavenging birds, including part of the left haunch extending to the knee joint, entrails, left elbow and shoulder. Most of the organs were resting in the body cavity encased in thick layers of fat. No abnormalities were apparent and the Cougar appeared to be in excellent condition prior to being killed.

Dozens of bites and subcutaneous hemorrhages were evident throughout the hide, with a concentration of trauma on the left chest, flank, throat, and top of the skull. Severe trauma was apparent on the neck 8 cm posterior to the skull, along the spine 10 cm posterior to the shoulder attachment, and along the sternum. The trachea was torn, and surrounded by massive hemorrhages. One bite apparently spanned the top of the skull with one canine puncture anterior

to the left ear and another canine puncture at the base of the right ear. The right masseter muscle was bruised and torn. There was a large tear in the tongue where the Cougar's canine tore through it, and a bruise in the center of the palate. It appeared that several Wolves attacked the Cougar and grabbed it numerous times with non-lethal bites. Eventually a fatal bite was inflicted when a Wolf grabbed the Cougar's throat and crushed the trachea.

Cougars and Wolves frequent the same ungulate wintering ranges in Glacier National Park, and share resources spatially but usually avoid each other temporally. We have documented Cougars scavenging on Wolf kills and vice versa. Direct encounters occur infrequently, but may result in a conflict situation in which death may occur if escape is not possible.

Acknowledgments

Funding for The Wolf Ecology Project was provided by a joint cooperative agreement by the National Park Service, The U.S. Fish and Wildlife Service, and the U.S. Forest Service, through the University of Montana. D. Hoerner's excellent piloting skills made possible our aerial observations of the Wolf-Cougar interactions. Many thanks to B. W. O'Gara for performing the Cougar necropsy. D. H. Pletscher, R. R. Ream, and M. W. Fairchild helped in many ways. L. D. Mech and P. C. Paquet made valuable comments on the manuscript.

Literature Cited

Allen, D. L. 1979. Wolves of Minong. Houghton Mifflin Company, Boston. 499 pages.

Boyd , D. K., and **B. W. O'Gara.** 1985. Cougar predation on coyotes. The Murrelet 66: 17.

Burkholder, B. L. 1962. Observations concerning wolverine. Journal of Mammalogy 43: 263–264.

Carbyn, L. N. 1982. Coyote population fluctuations and spatial distribution in relation to Wolf territories in Riding Mountain National Park, Manitoba. Canadian Field-Naturalist 96(2): 176–183.

Fuller, T. K., and **L. B. Keith.** 1981. Non-overlapping ranges of coyotes and wolves in northeastern Alberta. Journal of Mammalogy 62: 403–405.

Mech, L. D. 1970. The wolf: the ecology and behavior of an endangered species. Natural History Press, Garden City, New York. 384 pages.

Paquet, P. C. 1991. Winter spatial relationships of wolves and coyotes in Riding Mountain National Park, Manitoba. Journal of Mammalogy 72(2): 397–401.

Paquet, P. C., and **L. N. Carbyn.** 1986. Wolves, *Canis lupus*, killing denning Black Bears, *Ursus americanus*, in the Riding Mountain National Park area. Canadian Field-Naturalist 100(3): 371–372.

Rogers, L. L., and **L. D. Mech.** 1981. Interactions of wolves and black bears in northeastern Minnesota. Journal of Mammalogy 62: 434–436.

Schmidt, K. P., and **J. R. Gunson.** 1985. Evaluation of wolf-ungulate predation near Nordegg, Alberta: second year progress report, 1984-85. Alberta Energy and Natural Resources Fish and Wildlife Division. 53 pages.

White, P. A., and **D. K. Boyd.** 1989. A Cougar, *Felis concolor*, killed and eaten by Gray Wolves, *Canis lupus*, in Glacier National Park, Montana. Canadian Field-Naturalist 103(3): 408–409.

Received 26 February 1992
Accepted 27 July 1993

A Wolf, *Canis lupus,* Killed in an Avalanche in Southwestern Alberta.

DIANE K. BOYD[1], LEE B. SECREST[2], AND DANIEL H. PLETSCHER[1]

[1]School of Forestry, University of Montana, Missoula, Montana 59812
[2]North Fork Road, Polebridge, Montana 59928

Boyd, Diane K., Lee B. Secrest, and Daniel H. Pletscher. 1992. A Wolf, *Canis lupus,* killed in an avalanche in southwestern Alberta. Canadian Field-Naturalist 106(4): 526.

A 22-month old Gray Wolf (*Canis lupus*) was killed by an avalanche in southwestern Alberta. Wolf mortality caused by an avalanche is a rare event and has been reported only once previously in the literature.

Key Words: Gray Wolf, *Canis lupus*, avalanche, Alberta.

Herein we document a Gray Wolf (*Canis lupus*) killed by an avalanche. The only other record of avalanche-caused Wolf mortality was that of Mech (1991) who reported the deaths of two Wolves in Denali National Park, Alaska, killed simultaneously by an avalanche.

Radio-collared W9014, a male, 22-month old Gray Wolf and sibling female W9064 (also radio-collared) dispersed from their pack in southeastern British Columbia between 14-18 February 1991. They were observed resting together in southwestern Alberta on 27 February 1991, 40 km east of their natal pack.

On 10 April 1991, W9014 was located in an avalanche chute near Drywood Creek, Alberta, at UTM 5460.2 N X 709.4 E, with his mortality signal activated. The same day W9064 was located 70 km west of W9014. Attempts were made to retrieve W9014's remains on 15 April and 9 May, but were unsuccessful due to the depth and instability of the snow in the chute.

On 16 June we retrieved his remains from the nearly snow-free chute. He had not slid any farther downslope from where we had flagged his location on 15 April. The chute was approximately 13 m deep and 25 m wide. Scavengers had fed upon his decomposing carcass, but the body was still 90% intact. No evidence of bullet wounds was apparent. Because of the extremely rugged terrain and lack of access, it was very unlikely that W9014 was killed by humans either from aircraft or the ground and was coincidentally caught in an avalanche; we presume the wolf was killed by the avalanche when caught in the flow.

Acknowledgments

Funding for this study was provided by the U.S. Fish and Wildlife Service, National Park Service, and U.S. Forest Service. We thank R. Ream, M. Fairchild, and D. Hoerner for their valuable assistance.

Literature Cited

Mech, L. D., T. J. Meier, J. W. Burch, and **L. G. Adams**. 1991. Demography and distribution of wolves, Denali National Park and Preserve, Alaska - Progress Report, 1986-90. Natural Resources Progress Report AR-91/01.

Received 26 February 1992
Accepted 27 July 1993

News and Comment

New Honorary Membership and 1991 Awards of The Ottawa Field-Naturalists' Club

One Honorary Membership and the 1991 OFNC awards were presented at the spring Soirée, held on 29 May, 1992. In December 1991 we lost George H. McGee, an Honorary Member who has left a tremendous record of teaching people about birds and their behaviour. Since then, Louise de Kiriline Lawrence, another ornithologically-experienced Honorary Member, has also passed away.

The Awards Committee named candidates for all four Club awards, and all recipients were able to attend the Soirée and to receive certificates and citations in person. The citations, including the new Honorary Membership, are provided below.

Our current President, Frank Pope, was unfortunately not able to be present. Colin Gaskell, Chairman of Excursions and Lectures Committee, hosted the Soirée.

The modern President's Prize, re-introduced in 1985, is also presented at the Soirée. The seventh of these prizes went to Larry Neily who was selected by Roy John, President in 1991 but unfortunately no longer in Ottawa.

Honorary Membership: Ellaine Dickson

One of the first contacts new members have with The Ottawa Field-Naturalists' Club is through Ellaine Dickson. Either by her friendly voice at the other end of the telephone or by her smiling face as you are welcomed to a Club function, Ellaine makes you feel right at home.

Ellaine has been a member of OFNC since 1968 and has been a truly active participant. Except for a two year break, she has served on Council since 1978. During that time she was a committed member of various committees - in fact, you could say that she was the driving force on some of them! They included Membership, Excursions and Lectures, Nominations and, more recently, Macoun Field Club.

Since 1976 the Club telephone has been kept at Ellaine's home and she has generously answered many enquiries throughout the years. When she wasn't booking members on outings or giving out information about the next meeting, Ellaine would be organizing the membership files which she maintained so meticulously over several years. If you wanted to know what was going on in the Club you phoned Ellaine.

Her home was a place where many committees met and where you could drop in to say hello. She is willing to share her knowledge of plants and birds and her enthusiasm for life with young and old. The same qualities are shown in her carvings of wildlife. For years her bird carvings have been presented to winners of the Anne Hanes Natural History Award.

Ellaine received the Member of the Year Award in 1985 and the Service Award in 1981. She is a real people person and a very dedicated individual.

George McGee Service Award: Bill Gummer

The OFNC Service Award is given to the Club member who has contributed significantly to the smooth running of the Club over several years.

This year the Club is pleased to present this award to Bill Gummer in recognition of the many contributions - both large and small - that he has made to the Club.

A Club member since 1971, Bill is an example of someone who really gets involved. As a member of Council since 1980, Bill has served as Corresponding Secretary (1981 to 1984), Vice-president (1984 to 1985) and President (1986 to 1988). He has also been chairman of the Nominating and Awards Committees and has served on the Publications Committee. During his period on Council he undertook the arduous task of updating and organizing the Club's Terms of Reference, the Constitution and the By-laws.

When Bill was not participating in Council matters he spent his time as Associate Editor of *Trail & Landscape*, a position which he has held almost continuously since 1980. He even found time to write

articles for *Trail & Landscape*. One of his most significant contributions to the Club has been the production of the 20 year index of *Trail & Landscape*. This is a cross-referenced subject/author index which was no mean feat to pull together in the pre-computer era.

Bill has shared his love of nature through leading excursions and through photography.

The Club is pleased to recognize Bill Gummer for his dedication and hard work and for his willingness to step in when a capable leader was needed.

1991 Member of the Year Award Citation: Michael Murphy

The Member of the Year Award recognizes an individual (other than members of the Executive) who has provided exceptional service to the OFNC during the previous year, preferably in a variety of ways. The diversity of roles undertaken by this year's designate certainly satisfies that criterion. So it is that Michael Murphy has been selected as the recipient of the 1991 OFNC Member of the Year Award.

If there was a local conservation issue before the public eye in 1991 one could be sure that Michael was near at hand to make sure that the concerns of The Ottawa Field-Naturalists' Club were heard. He represented the OFNC and other conservation interests at innumerable municipal meetings, public hearings, media events and technical committees. This is a very important role since the presence of an effective representative at the right time can make the difference between quickly saving an important resource and undertaking a long, messy battle to do so. In this increasingly complex world it is often difficult to find capable people able to take personal time during office hours to attend such events. Time and time again Michael found a way to do so. While his public representations, especially those covered in the media, are the best known aspect of his conservation efforts, he had at least as much to say and was at least as effective behind the scenes.

Michael developed and produces *The Green Line*, the popular conservation newsletter that is inserted into each issue of *Trail & Landscape*. Not content with just handling this, however, he also expedites the mailing of each issue of *Trail & Landscape*.

An active member of the Computer Management Committee for some time, he is now Chairman and has initiated a variety of software and hardware undertakings to upgrade and enhance the management of OFNC information systems.

In addition to his active involvement in a wide range of Council discussions, including frequent reports on behalf of the Conservation Committee, Michael is a regular participant at OFNC monthly meetings and undertook the judging of Ottawa Regional Science Fair entries for the OFNC Science Fair Prizes.

Without energetic individuals pushing from behind and pulling from ahead it is easy for volunteer organizations like the OFNC to become inwardly focused, to become stale and aimless. It will be through the committed efforts of individual members, like those exhibited by Michael Murphy in 1991, that we can avoid this trap and continue to make the OFNC a relevant and important environmental organization in the Ottawa Valley and beyond.

1991 OFNC Conservation Award Citation: Albert Dugal

Once a person has been acknowledged for exceptional achievements in a particular field there is a tendency - perhaps unconsciously - to no longer think of them as an award candidate. Such was probably the case with this award as the 1991 recipient has been acknowledged once already and could have been again in any of a number of years. We speak of Albert Dugal, the 1981 and now, 1991 recipient of the OFNC Conservation Award.

Albert has been a committed and persistent participant in the conservation activities of the OFNC (and as a private individual) for over a decade. Never one to be influenced by the "winnability" of a situation, he has lobbied, argued and demonstrated for the protection of important natural areas across the Regional Municipality of Ottawa-Carleton. One of the most important aspects of this has been the thorough floristic inventories he has undertaken of several contentious areas. These floristic data have proven to be a valuable tool in delineating areas of natural significance in many parts of the Region, including Morris Island, the South Gloucester and Osgoode-Metcalfe area, and the Leitrim (Albion) Wetlands in Gloucester.

The Leitrim Wetlands situation is a particularly good example of the value of Albert's work. Upon learning of a development proposal here, he undertook an investigation of the site. In the course of his studies he discovered literally dozens of rare and significant plant species, including some previously not recorded from the Ottawa area. These data were critical in assessing the importance of this provincially significant wetland. His *Trail & Landscape* article in 1990, on the flora and vegetation of the wetland was so thorough that it has been used as a primary reference by various parties with an interest in the wetland

at subsequent Ontario Municipal Board (OMB) hearings. His work in the Leitrim Wetlands has led to a large critical core area of the wetland being set aside by order of the OMB. His findings are also providing helpful information in the process of negotiating the size of a protective buffer zone around this core.

If there is a problem with awarding the OFNC Conservation Award to Albert Dugal in 1991 it is that his exceptional achievement may diminish our ability to appreciate valuable conservation contributions of others. He has literally set a new standard of excellence. What a fine "problem" to have!

1991 Anne Hanes Natural History Award Citation : Michael Runtz

The Anne Hanes Award recognizes excellence in the performance of field naturalist pursuits in the Ottawa Valley, not just the Ottawa District. That, in turn, reflects Anne Hane's vision of this land and an appreciation that the Ottawa area is part of a larger landscape. The presentation of the 1991 Anne Hanes Natural History Award supports that commitment by recognizing one of the Ottawa Valley's most prominent naturalists, Michael Runtz of Arnprior.

Michael's keenness and enthusiasm for birding and field ornithology since the early 1970s have become something of a local legend. First in the Arnprior-Pakenham area, then broadening into the larger Ottawa-Hull region and, most recently, northwestward into Algonquin Park, he has built an expert understanding of the bird populations of the Ottawa Valley. He took on increasingly large roles in the Arnprior and Pakenham Christmas Counts and an active role with the OFNC Bird Committee.

Michael has broadened his zoological focus to include mammals, reptiles and amphibians and insects. Over the last twenty years he has contributed numerous useful and interesting observations to various zoological data bases, including the *Ontario Herpetofaunal Summary* and the *Breeding Bird Atlas of Ontario.*

Botanical interests - especially orchids - and his work in provincial parks spurred on his involvement in conservation activities. In the 1980s he successfully spearheaded the effort to establish the Federation of Ontario Naturalists, nature reserve at Stewartville near Arnprior and he is presently deeply involved with Arnprior's Save the Grove Committee; they are attempting to save the old Gillies Estate forest from urban development.

In the course of over twenty years of careful, persistent work based as it should be on sound, well-researched information, Michael Runtz has developed a well-rounded expertise concerning natural history features and values in the Ottawa Valley. His strong personal commitment to and knowledge of the natural world are made abundantly clear in frequent speaking engagements, be they in the Natural History of Canada course he teaches at Carleton University, his talks to local natural history organizations or in public presentations in provincial parks.

This flair for presentation is also expressed in a love of wildlife photography which he embraced with typical no-holds-barred enthusiasm. The spectacular results of that commitment are seen in *Moose Country: Saga of Woodland Moose* which he wrote and illustrated in 1991.

Michael Runtz is a naturalist of the Anne Hanes School. He has earned this high praise through his important contributions to the natural world - and to naturalists - throughout the Ottawa Valley.

ENID FRANKTON
Chairman, Awards Committee

President's Prize 1991: Larry Neily

Larry Neily has kept the Bird Status Line going since he took it over in the summer of 1986. In an article in *Trail & Landscape,* Larry reported that the line was being accessed about 250 times per week in 1988. Although a counter is no longer attached to the line, he estimates that the access rate has even increased since then.

This prize is in recognition of Larry's excellent performance in a difficult political task. It is one in which a person is lucky to please half the callers, let alone all of them. Larry has succeeded by a combination of tact and diplomacy, backed up by a comprehensive knowledge of his subject.

Callers from out of town and first time callers are impressed by his friendly reponse, the interest he takes in their call, and the time he is prepared to give them.

The more experienced birders appreciate another contribution. Since the demise of *The Shrike* and the bird observation data base, Larry's telephone logs have been the main source of data for the bird observation reports that are published in *Trail & Landscape.*

ROY JOHN
President (1991) Ottawa Field-Naturalists' Club

Additional Proposals for the Revised Constitution of The Ottawa Field-Naturalists' Club

In Volume 106, Number 2, a request was made for additional proposals regarding the revised constitution published in Volume 106, Number 1, and subsequently adopted provisionally at the 114th Annual Business Meeting. The request for additional comments was made because Volume 106, Number 1, was delivered to members less than 30 days before the Annual Business Meeting.

One proposal has been received. It is to delete Article 17(c) which allows for amendments consisting of groups of new or revised articles in the case of a major revision to the Constitution.

This proposal will be considered at the 115th Annual Business Meeting, to be held in Ottawa on 11 January 1994. At that time the members will be asked to ratify the constitution provisionally adopted a year earlier.

FRANK POPE

President, Ottawa Field-Naturalists' Club

Notice of the 1994 Annual Business Meeting of The Ottawa Field-Naturalists' Club

The 115th Annual Business Meeting of The Ottawa Field-Naturalists' Club will be held in the auditorium of the Victoria Memorial Museum Building, McLeod and Metcalfe streets, Ottawa on Tuesday 11 January 1994 at 19:30 h.

STEPHEN GAWN

Recording Secretary

Call for Nominations: The Ottawa Field-Naturalists' Club 1993 Awards

Nominations are requested from Ottawa Field-Naturalists' Club members for the following: Honorary Membership, Member of the Year, George McGee Service Award Citation, Conservation, and the Ann Hanes Natural History Award. Descriptions of these awards appeared in *The Canadian Field-Naturalist* 96(3): 367 (1982). With the exception of nominations for Honorary Member, all nominees must be Club members in good standing.

ENID FRANKTON

Chair, Awards Committee

Call for Nominations: The Ottawa Field-Naturalists' Club 1994 Council

Candidates for Council may be nominated by any Ottawa Field Naturalists' Club member. Nominations require the signature of the nominator and a statement of willingness to serve in the position for which nominated by the nominee. Some relevant background information on the nominee should be also provided.

W. K. GUMMER

Chair, Nominating Committee

Wolf Scientists Meet in Edmonton

H. Dean Cluff

Department of Zoology, University of Alberta, Edmonton
Present address: Wildlife Management Division, Government of the Northwest Territories, Yellowknife, Northwest Territories X1A 358

Cluff, H. Dean. 1992. Wolf scientists meet in Edmonton. Canadian Field-Naturalist 106(4): 531–533.

The Gray Wolf (*Canis lupus*), perceived by many as a symbol of wilderness, is the most studied carnivore, challenged only by the closely related Coyote (*C. latrans*). Perhaps surprisingly, then, efforts to host a major symposium on wolves would be seen as superfluous. However, the need could not be greater. Because of the intense interest that the wolf generates and its wide distribution over three continents, a thorough discussion of the wolf's current status, biology and management would be just what is required.

Dr. Ludwig Carbyn of the Canadian Wildlife Service (CWS) and the Canadian Circumpolar Institute (CCI) did just that. Having organized the first symposium in 1981, he convened The Second North American Symposium On Wolves: Their Status, Biology and Management from 25-27 August 1992 at the University of Alberta in Edmonton. Sponsored by CWS, CCI, Wolf Haven International, US Fish and Wildlife Service (USFWS), US Department of Agriculture, World Wildlife Fund (Canada), and the Canadian Nature Federation, the symposium was assured to be well received. In fact, official registration numbered 380 delegates, a significant increase over the 260 originally expected while also taxing the capacity of the facilities that were scheduled for the event. Any inconvenience, however, was offset by all proceeds from the symposium (about $3200) going to assist wolf conservation efforts in India, an area where wildlife is literally losing its ground as the seemingly endless quest for land by humans continues unabated.

Although dominated by wolf research originating in North America, Carbyn encouraged efforts from abroad and actively sought a global perspective on issues relating to wolves. Luigi Boitani (University of Rome, Italy), Ruud Derix and Jan Van Hooff (University of Utrecht, The Netherlands), Karl-Heinz Frommolt (Humboldt-University of Berlin, Germany) and Alexander A. Nikol'skij (University of Moscow, Russia) were featured in speaker presentations. Furthermore, nine poster presentations were given concerning the behavior or status and management of wolves in China, Finland, Germany, Greenland, India, Poland, Romania, Spain, and the former USSR. The international representation was aided by the meeting of the Wolf Specialists' Group of the International Union for the Conservation of Nature and Natural Resources (IUCN) held during the symposium.

Three main issues concerning wolves were highlighted at the symposium. The Gray Wolf reintroduction program currently under review in Yellowstone National Park, the taxonomy of wolves and related canids, specifically the distinction between Gray Wolves and Red Wolves (*C. rufus* as currently classified), and the evaluation of methods to achieve wolf population control all contributed to the success of the symposium. The three issues were timely discussions and underscored many of the implications facing wolf recovery teams in Yellowstone, the southeast United States (Red Wolf), and abroad.

Wolves in Yellowstone is a contentious issue and has been for years. Diametrically opposed views exist between ranchers concerned about the inevitable depredation of some livestock by wolves and traditionists who argue that only wolves now remain absent in an ecosytem gone awry without their presence. Interestingly, Charles E. Kay (Utah State University) questioned the historical abundance of ungulates and specifically of wolves in the Yellowstone area between 1835 and 1876. Kay based his argument on observational reports of first-person journals written by visitors to the region at that time. Paul Schullery (US National Park Service) and Lee Whittlesey (Yellowstone National Park consultant) challenged Kay's view based on their extensive search of literature from 1806 to 1881. Schullery and Whittlesey argued that ungulates and wolves were sufficiently abundant in Yellowstone during the window of time that they examined and that wolves were an integral part of the Yellowstone ecosystem. However, these authors acknowledged the limitation of their faunal record to allow precise comparisons with animal populations now present in the area. Steven H. Fritts (USFWS) summarized the status of wolf recovery programs in the northern Rockies of the US, identifying Yellowstone as the most controversial. Together with USFWS and US Parks Service colleagues Edward E. Bangs, Wayne

G. Brewster, Joseph Fontaine, and Jay F. Gore, Fritts acknowledged the exceedingly delicate issues their agencies must face in implementing the recovery of species listed in the Endangered Species Act of which the wolf is but one species, albeit a highly emotional one. Whether the Gray Wolf can be removed from the threatened and endangered species lists for the lower 48 states remains to be seen. Certainly, efforts of many researchers such as the simulations used by Mark S. Boyce to project the consequences of wolf recovery to ungulate populations will draw close scrutiny.

Taxonomy was another major theme of the symposium. Robert K. Wayne, currently at the Zoological Society of London, began the discussions with a review of the molecular-genetic analyses of Gray Wolves and related canids. Compelling evidence from mitochondrial DNA suggested at least seven hybridization events have occurred between the wolf and Coyote in Minnesota and eastern Canada. Wayne and his coauthors, Niles Lehman (The Scripps Research Institute), and Todd K. Fuller (University of Massachusetts), argued that a more ancient hybrid zone between Gray Wolves and Coyotes may have occurred in the American south and southeast and that this hybridization may have influenced the phenotype of the Red Wolf.

Following on the heels of Wayne's talk, Ronald M. Nowak, of the USFWS, gave a dramatic delivery of morphometric data that he and coauthors M.K. Phillips, V.G. Henry, W.C. Hunter (all from the USFWS), and R.S. Smith (Point Defiance Zoo and Aquarium) had analyzed. The authors did not deny that hybridization had occurred between wolves and Coyotes, but based on new fossil evidence, they argued that the Red Wolf is indeed a distinct species from the Coyote and Gray Wolf. Nowak and his coauthers further believe that the Red Wolf is an ancestor to all wolves, such as the Gray Wolf and the extinct Dire Wolf (*C. dirus*). The back-to-back presentations stimulated much discussion not only on the repercussions for endangered species recovery programs but on the traditional and genetic approach to taxonomy.

The third major area of contention in wolf biology and management highlighted at the symposium was the intentional removal and control of wolves by wildlife managers to reduce depredations on livestock and to reduce declines in, or otherwise augment, ungulate populations, the latter primarily used to benefit hunters. Three lead-in talks were given by Rodney D. Boertje and co-researchers from Alaska Department of Fish and Game (ADF&G), Raymond Coppinger from Hampshire College, and Cheryl S. Asa from the St. Louis Zoo that addressed non-lethal methods of wolf control. Boertje summarized ADF&G experiments that provided supplemental food to wolves, Grizzly Bears (*Ursus arctos*) and Black Bears (*U. americanus*) during calving periods for Moose (*Alces alces*) and Caribou (*Rangifer tarandus*). Such diversionary feeding to reduce predation on these ungulates showed some promise as a non-lethal method of controlling wolves but its effectiveness is heavily dependent upon scale of effort and overall cost-effectiveness. Coppinger eloquently presented his 15 years of work using guard dogs as a preventative measure in livestock depredation by wolves. Coppinger stressed that the method is not an immediate response to a wolf-livestock problem because guard dogs must be properly socialized to the animals they are to protect. Asa outlined contraceptive approaches as a way to reduce or eliminate wolf conflicts. Techniques such as steroid hormones, immunocontraceptives, chemical sterilization and castration will influence physiological and behavioral processes in individuals. Whether the integrity of the wolf pack as the social unit is preserved remains largely unknown. The uncertainty arises from the potential breakdown in the maintenance of a dominance hierarchy by the so-called alpha mated-pair towards its pack mates to the social repercussions associated with the absence of a litter in the pack.

Further talks that wrestled with wolf control issues were led by Roger Reid (British Columbia Wildlife Branch), Gordon C. Haber (Denali National Park consultant), E. D. Bangs, Roy McBride (Rancher's Supply), and Robert O. Stephenson (ADF&G) as well as a number of poster presentations. The theme common to most was the importance that public acceptance (or opposition — depending on your view) plays in shaping the development and use of a particular technique. In another stimulating presentation, Rolf O. Peterson (Michigan Technological University) considered the evidence of wolves as interspecific competitors in a size-based hierarchy of predators. Peterson included habitat structure (open vs. vegetated) and the presence of humans as contributing to the outcome of interference competition. Furthermore, humans may function as a keystone species thereby facilitating the survival of small canids that might otherwise be excluded by the larger species. University of Montana researchers Robert Ream, Dan Pletscher, Diane Boyd, and Mike Fairchild made extensive use of a Geographic Information System (GIS) and traditional tracking data from radio-collared wolves to map out travel corridors in an area dominated by rugged mountains. Wolves made regular use of the broad valley bottom and frequented open areas (meadows, frozen marshes and lakes, river flood plains) and travel routes that connected these areas. Ream and coauthors contend that the visual detection of prey is an important component in the pack hunting strategy and that vegetation density and prey distribution influence travel patterns.

L. David Mech (USFWS), perhaps the world's foremost authority on wolves today, outlined gaps in our knowledge concerning wolves and the ways and means with which we might go about acquiring this information. Mech discussed issues relating to the wolf's biology, behavior, and the yet-to-be-resolved controversy surrounding the impact of wolves on their prey. Mech encourages a long-term approach to wolf research partly because of the longevity of wolves and most of their prey and the changes that ensue in long-lived species. Having been actively involved in the two longest running predator-prey systems (wolves and Moose in Isle Royale in Lake Superior, and wolves and deer in northeastern Minnesota), Mech's efforts can attest to the impact that these studies have had in shaping our understanding of the wolf and its role in the ecosystem. As Mech and others have pointed out, we have made significant inroads in understanding the wolf since our blatant attempts to totally eradicate the species which have occurred throughout much of human history. However, we still have a long way to go. Mech's analysis, together with the other 88 papers submitted to the symposium's proceedings (expected in November 1993 after completion of peer reviews), will focus research activity for the years ahead. Perhaps when the third North American Symposium on Wolves convenes a decade or so from now, we may finally come to understand a species so dear to some and so deeply hated by others.

Received 8 December 1992
Accepted 10 April 1993

The Thread-leaved Sundew, *Drosera filiformis* in Nova Scotia: An Assessment of Risks of a Proposal to Mine Fuel Peat from its Habitat

B. Freedman[1], W. Maass[2], and P. Parfenov[3]

[1]Department of Biology and School for Resource and Environmental Studies, Dalhousie University, Halifax, Nova Scotia B3H 4J1.

[2]General Delivery, Ketch Harbour, Nova Scotia B0J 1X0

[3]Laboratory of Phytomonitoring, Institute of Experimental Botany, Minsk, Byelorus

Freedman, B., W. Maass, and P. Parfenov. 1992. The Thread-leaved Sundew, *Drosera filiformis,* in Nova Scotia: An assessment of risks of a proposal to mine fuel peat from its habitat. Canadian Field-Naturalist 106(4): 534–542.

Drosera filiformis Raf. is a rare and endangered species that only occurs in Canada in four raised bogs, all in Shelburne County, Nova Scotia. One of these sites has been proposed for development as a fuel-peat mine. An assessment that focused on *D. filiformis* and its habitat concluded that the peat mining would pose substantial direct and indirect risks to the survival the species in Canada. As a result, the proposed project was not allowed to proceed. This represents a rare case in which consideration for the integrity of a rare and endangered species of plant has resulted in blocking of a proposed resource-extraction development.

Key Words: Thread-leaved Sundew, *Drosera filiformis,* Nova Scotia, endangered species, risk assessment, raised bogs, peat mining.

Drosera filiformis Raf., the Thread-leaved Sundew (Figure 1), is only known in Canada from four raised (or plateau) bogs, all in Shelburne County, Nova Scotia (Hill and Zinck 1990; Zinck 1991). This species is considered to be rare in Nova Scotia (Maher et al. 1978) and in Canada (Argus and Pryer 1990), and it has been listed as an "endangered" species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Zinck 1991), implying that it "is threatened with imminent extinction or extirpation throughout all or a significant portion of its Canadian range" (COSEWIC 1991).

Drosera filiformis has a much-larger range in the eastern United States than in Canada (Fernald 1918; Wynne 1944; Gleason 1952; Maher et al. 1978; Juniper et al. 1989). The species is most abundant in the southeastern U.S., particularly along the Gulf Coast of Florida to Louisiana. There are less-frequent occurrences in Georgia and South Carolina, and disjunct populations from Massachusetts to Delaware. *Drosera filiformis* has been designated as rare and/or endangered in Connecticut, Georgia, New York, North Carolina, and Rhode Island (Maher et al. 1978; Anonymous 1990; Zinck 1991). All locations of *D. filiformis* are close to the coasts of the Gulf of Mexico or the Atlantic Ocean.

The disjunct populations of *D. filiformis* in southwestern Nova Scotia are part of a coastal-plain floristic element involving various species that are rare or unknown elsewhere in Canada (Fernald 1918; Roland and Smith 1969). The populations of *D. filiformis* and other coastal-plain species may be relicts of a once more-widely distributed flora that ranged broadly along the exposed continental shelf during periods of lower sea level during the Quaternary. At times, a land-bridge may have extended from Cape Cod to southwestern Nova Scotia, and as recently as 5000 years ago there was what may have been a substantial remnant archipelago of that landform (Bousfield and Thomas 1975; Roland 1982). Postglacial sea-level rise isolated the coastal-plain elements in Nova Scotia from more-broadly distributed communities of this type in the United States. The Coastal Plain Flora is comprised generally of rare species, and a large fraction of its elements in Nova Scotia and more broadly in Canada is endangered (Maher et al. 1978; Keddy 1979, 1985).

The Canadian site with the largest, least-disturbed populations of *D. filiformis* has been proposed for industrial development as a fuel-peat mine. Peat extracted from bogs has been advocated as an indigenous but non-renewable source of energy that might be economically exploited in Nova Scotia (Anrep 1915; Tarnocai 1984; Anderson and Broughm 1988).

Peat has long been used for energy purposes in Europe, initially for domestic and small-industrial purposes. However, since the Second World War there has been extensive mining of peat for the centralized production of energy for electricity and district heating, particularly in the pursuit of national energy policies in Ireland, Finland, and Russia (Johnson 1985). The extensive mining of peat in Europe has been accompanied, however, by substantial environmental damages and controversy (Johnson 1985; Winkler and DeWitt 1985). There have been significant losses of conservation values, with some peat-producing wetland types virtually

FIGURE 1. The Thread-leaved Sundew, *Drosera filiformis* a.k.a. The fruiting scape is about 13 cm long. Photographed at Swaine's Road Bog, Nova Scotia in the late summer, near the end of the growing season.

disappearing over extensive areas, and plant species becoming endangered or regionally extinct (Larsen 1982; Johnson 1985).

In the present report, we describe the results of an assessment undertaken on behalf of the Nova Scotia Department of the Environment (NSDOE) to address the potential effects on *D. filiformis* and its habitat of the commercial extraction of peat from a wetland known as Swaine's Road Bog. We studied aspects of the autecology, community ecology, and habitat of *D. filiformis* at its known sites in Nova Scotia, and then evaluated the risks potentially posed by peat mining by consideration of: (1) the direct risks of the proposed peat extraction to *D. filiformis* in Swaine's Road Bog; (2) the indirect risks of peat extraction to *D. filiformis* in habitat contiguous with the proposed mine area; and (3) the wider distribution of *D. filiformis* in southwestern Nova Scotia.

Methods

A total of 16 bogs was investigated in southwestern Nova Scotia during fieldwork in August and September, 1991. At sites with a population of *D. filiformis*, visual estimates were made of percent cover of all species of bryophytes, lichens, and vascular plants occurring in ten, widely spaced, 1m x 1m quadrats. Quadrat placement was stratified by a requirement for inclusion of individuals of *D. filiformis*, with a view to describing the community of that species within the context of its immediately associated vegetation. A random placement of quadrats within the bogs was precluded by the relatively restricted distribution and small cover of *D. filiformis* at all sites, and by the immediate needs of our research in terms of impact assessment. From the field data, calculations were made of average percent cover, frequency of occurrence, and prominence (i.e., cover x square-root frequency; Beals 1960) of each plant species.

Growth form and vigor of individuals of *D. filiformis* were described in terms of foliar number, length of the longest leaf, number and length of flowering scapes, and maximum diameter and position of the tuber. Measurements were made within 1m x 1m quadrats until at least fifty plants were tallied, which required 2-3 quadrats per site.

Samples of surface peat and interstitial bogwater were collected for analysis of selected chemical constituents. At each site, water samples were taken from duplicate pits of 40-75 cm depth, dug in the immediate vicinity of plants of *D. filiformis,* and allowed to infill for 20 minutes. Samples were allowed to stand for >2 days in a refrigerator, decanted, and the supernatant analyzed for pH, calcium, and magnesium. Four samples of surface peat were collected from the immediate vicinity of plants of *D. filiformis*, mixed with 50% (v:v) distilled water, and analyzed for pH after standing for 1 day.

In 1986, one of us (WM) transplanted 12 individuals of *D. filiformis* to a small coastal bog near Chebucto Head in Halifax County. The transplant site has most of the plant associates of *D. filiformis* in its natural habitats in southwestern Nova Scotia. The transplants were obtained in September as tubers complete with 5-cm-diameter peat plugs from Swaine's Road Bog. To assess the short-term success

of the transplantation, in September 1991 a search was made for individuals of *D. filiformis* in the transplant area. Each was tallied, the overall distribution of plants was noted, and individuals were measured for growth form and vigor as described above.

Results and Disussion

1. Drosera filiformis *in Nova Scotia.*

Only four of the 16 plateau bogs investigated in southwestern Nova Scotia have populations of *D. filiformis*, all of these previously known (Zinck 1991).

At Swaine's Road Bog (43°34'N; 65°32'W), [Figure 2] we examined the following sites:

(1) the location of the proposed, pilot-phase, peat extraction has an estimated population of *D. filiformis* in the middle-thousands (i.e., 3-7 thousand) of individuals.

(2) a "near-field" site extending to 150 m beyond the SE boundary of the site of the proposed mine, with an estimated population of *D. filiformis* in the middle-thousands of individuals. The near-field site is not proposed for immediate harvesting, but is in a reasonably anticipated spatial range for environmental influences of the pilot project. For example, the site could be incidentally disturbed or stressed by a drawdown of the watertable caused by harvesting or the planned ditching of the perimeter of the harvest area.

(3) a "far-field" site extending to 0.5-1.0 km from the SE boundary of the proposed Pilot Project, with an estimated population of *D. filiformis* in the middle-thousands of individuals. This site is not proposed for immediate harvesting, but it is

TABLE 1. Prominence values of selected, most-abundant plants associated with *Drosera filiformis* at its known sites of occurrence in Nova Scotia. See text for more information on the sites. Data for less-frequent species are in Freedman et al. (1991).

	Swaine's Road Bog								
	Pilot	Near	Far	S. Judas Creek			Port	Quinn	Baccaro
Species	Proj	Fld	Fld	Bog	Hollow	Trail	Latour	Meadow	Bog
Andromeda glaucophylla	12	10	15	23	2	9	19	7	1
Aronia prunifolia	15	14	9	8	1	7	12	7	9
Aster nemoralis			3	<1	8	<1		<1	4
Calamagrostis pickeringii	4	9	2	1	1	<1			2
Carex exilis		<1	11			3	24	10	4
Chamaedaphne calyculata	2	5	3	4	2	9	15	4	<1
Cladina mitis	158	323	28	57	3	1	7	1	199
Cladina terrae-novae	61	14	1	118		5	16	13	6
Cladonia spp.				15					
Cladonia phyllophora	<1	6	2	6		<1	1	<1	2
C. cervicornis verticillata	12	8		8		1			
Cladopodiella fluitans			56						<1
Drosera filiformis	15	8	25	3	9	5	38	5	6
Eriophorum virginicum	2	1		6	<1	1	3		
Gaylussacia baccata			1	325	3	70			<1
Gaylussacia dumosa	275	192	78		<1	2	19	17	8
hepaticae	10	8	16	48	9	33	71	18	81
Ilex glabra			2			18			
Juniperus communis	30	3	8	7		1			
Kalmia angustifolia	20	22	4	20	<1	16	7	2	13
Rhynchospora alba			12	<1	208	11	19	21	17
Scirpus caespitosus	50	33	32	64	6	55	48	27	42
Solidago uliginosa	6	1	2	3		<1	4	7	6
Sphagnum cuspidatum			1			1	6	<1	37
Sphagnum flavicomans	6	27	<1	9		5	7	3	<1
Sphagnum fuscum	22	9		95		<1	1		
Sphagnum magellanicum		<1	3	<1	2	8	1	8	3
Sphagnum pulchrum						<1	3	79	
Sphagnum rubellum	59	47	41	242	29	380	11	131	194
Sphagnum tenellum	1	1	220	5	427	254	72	388	244
Vaccinium macrocarpon	<1	<1	27	<1	13	4	4	10	<1
Vaccinium oxycoccus	9	6	4	3	4	13	16	21	24
Zygonema sp.					13				
TOTAL PLANT COVER	90%	83%	67%	120%	83%	98%	50%	86%	100%
AVERAGE NO. SPECIES/m^2	17	18	19	22	11	20	19	20	18

FIGURE 2. Overview of the habitat of *Drosera filiformis* in a raised bog at Swaine's Road Bog, Nova Scotia. The visually most-prominent species is *Scirpus caespitosus*. See text for a description of other prominent species in the community.

in the spatial range for potential, longer-term hydrologic influences of the pilot project.

(4) a second far-field site in which *D. filiformis* occurs in three distinct microhabitats: (a) most extensively in a closed community of *Scirpus caespitosus* and ericaceous shrubs, (b) in sparsely vegetated, natural hollows and pans with bare-peat substrate, and (c) in bare-peat substrate associated with animal trails. The most vigorous individuals and regeneration of *D. filiformis* were associated with the disturbed, less-competitive, bare-peat microhabitats, and the total esti-

TABLE 2. Measures of the vigor of *Drosera filiformis* at its known sites in Nova Scotia. Average, standard deviation (S.D.), and sample size(n).

	Swaine's Road Bog							
	Site 1	Site 3	Site 4 Bog	Site 4 Muck	Site 4 Trail	Port Latour	Quinn's Meadow	Baccaro Bog
length of longest leaf (mm)	107	92	86	96	104	88	87	99
(S.D.)	± 24	± 20	± 31	± 24	± 35	± 21	± 23	± 26
(n)	76	71	83	90	123	79	74	55
number of leaves	3.3	4.6	4.0	3.3	4.2	3.2	2.9	4.1
(S.D.)	± 1.0	± 1.8	± 1.4	± 1.3	± 2.0	± 1.1	± 1.0	± 1.2
(n)	76	71	83	90	123	79	74	55
number of flowering stalks	0.3	0.5	0.4	0.1	0.4	0.4	0.1	0.9
(S.D.)	± 0.5	± 0.6	± 0.6	± 0.3	± 0.6	± 0.5	± 0.3	± 0.7
(n)	76	71	83	90	123	79	74	55
tuber diameter (mm)	4.8	6.5	4.4	4.1	5.3	4.4	4.2	5.9
(S.D.)	± 1.5	± 2.4	± 2.0	± 1.7	± 2.3	± 1.7	± 1.7	± 2.0
(n)	76	71	83	90	123	79	74	55
plant density (m^{-2})	25	36	21	90	41	40	25	12
(n)	3	2	4	1	3	2	3	6

mated population of *D. filiformis* is in the low-thousands of individuals.

Port Latour Bog (43°31' N; 65°30' W) is well-vegetated, but exposures of bare-peat substrate are common in natural hollows and in the frequent tracks of all-terrain vehicles (ATVs). *Drosera filiformis* is fairly abundant, widespread, and vigorous, with an estimated population in the high-tens of thousands of individuals.

Quinn's Meadow Bog (43°40' N; 65°28' W) is located on the east side of Clyde River. The site is well vegetated, with little bare substrate except in the frequent tracks of ATVs. *Drosera filiformis* has an estimated population in the middle-tens of thousands of individuals.

Baccaro Bog (43°27' N; 65°30' W) is well vegetated, with frequent exposures of bare-peat substrate in pools and within the frequent tracks of ATVs. Habitat that appears suitable for *D. filiformis* is widespread, but the species occurs in only one small locale within the bog, with an estimated population in the middle-thousands of individuals.

We extensively searched another 12 raised bogs in southwestern Nova Scotia (Freedman et al. 1991) that superficially appeared to have suitable habitat for *D. filiformis*, but this species was not found at any of these sites.

2. *The Plant Associates of* D. filiformis *in Nova Scotia.*

The most consistently prominent indicator of habitats with *D. filiformis* is the short-statured, caespitose rush, *Scirpus caespitosus* (Table 1). During our searches for new plateau-bog locales of *D. filiformis*, our initial assessment of habitat suitability was based on the visual prominence of *S. caespitosus* in the habitat.

On relatively drier and shrubbier microsites, the lichens *Cladina mitis, C. terrae-novae*, and *Cladonia cervicornis* are relatively prominent associates of *D. filiformis*, as are the shrubs *Aronia prunifolia, Gaylussacia baccata, G. dumosa, Juniperus communis,* and *Kalmia angustifolia*. On relatively wetter microsites with frequent exposures of peaty, poorly vegetated substrate, the peat moss *Sphagnum tenellum* is prominent, as are *Carex exilis, Rhynchospora alba*, and species of hepaticae.

3. *Vigor of* D. filiformis.

The population of *D. filiformis* at the proposed peat-mine at Swaine's Road Bog did not differ substantially in growth form or apparent vigor from plants at its other sites in Nova Scotia (Table 2). Plant density within the Swaine's Road Bog populations was somewhat larger than at Baccaro Bog, and smaller than at Port Latour Bog, but the differences are not substantial.

Effects of microsite within Swaine's Road Bog on vigor of *D. filiformis* were greater than differences among sites. Microsites typical of the dominant, well-vegetated portions of the bog (Site 4, Bog in Table 2) were compared with adjacent but much-less common, disturbed microsites in hollows and animal trails with exposed, wet, peaty substrate (Site 4, Hollow or Trail in Table 2). *Drosera filiformis* was most vigorous in the disturbed situations: leaf and flowering-stalk lengths were typically longer, tuber width larger, and density greater than in the undisturbed habitat. Disturbed microhabitats also had a relatively great abundance of small, non-flowering individuals that had been recently recruited into the population.

These observations are reasonable, considering the recognized intolerance of *D. filiformis*, and *Drosera* in general, to competitive stresses exerted by other plants (Juniper et al. 1989). We only observed vigorous regeneration of *D. filiformis* in situations with poorly vegetated, moist, peaty substrate, such as natural hollows, animal trails, and tracks of all-terrain vehicles. It appears that *D. filiformis* is tolerant of a limited intensity of disturbance, and may require micro-disturbance for the longer-term maintenance of vigorous populations.

4. *Other Habitat Characteristics.*

All of the sites supporting *D. filiformis* have acidic surface peat and interstitial water (both were pH 3.8-4.5 among the study sites). The acidity is due to the ombrotrophic character of these raised bogs, and the large concentrations of fulvic acids that give a dark-brown stain to the interstitial water (Freedman 1989).

Calcium and magnesium are also important in the chemistry of wetlands, because they contribute to acid-neutralization capability, they are plant nutrients that can be depleted by acidic drainage, and their rate of input to ombrotrophic bogs is small (Freedman 1989). Among the sites Ca concentrations in interstitial water were very small (range 0.4-1.4 mg/L) and similar to oligotrophic lakewaters in southwestern Nova Scotia (Freedman et al. 1989), while Mg ranged from 0.8-2.0 mg/L, about twice as large as in those lakes.

5. *Transplants of D. filiformis.*

Our observations of transplants to a coastal bog about 200 km NE of the natural range of *D. filiformis* indicate successful establishment and population growth, from 12 transplants to at least 40 individuals after five years. The growth form of the introduced plants is similar to that of *D. filiformis* elsewhere in Nova Scotia (Freedman et al. 1991). These are, of course, short-term observations, and nothing is known about the longer-term persistence or viability of the introduced population.

Observations of these transplants, coupled with knowledge that *D. filiformis* and some other species of *Drosera* are relatively easy to propagate from leaf cuttings, tubers, and sometimes seed (Lloyd 1942; Schwartz 1975; Juniper et al. 1989; Lecoufle 1991),

indicate that it might be possible to successfully transplant *D. filiformis* into suitable, natural habitats in Nova Scotia and perhaps elsewhere.

However, there are ethical considerations to any program designed to actively establish new colonies of a rare native species into formerly unoccupied sites. The Canadian Botanical Association has taken a strongly negative position on transplantation as the sole means of preserving rare species of plants (Fahselt 1988; CBA 1991). The rationale is that transplanting should be avoided except in extraordinary cases, and that from the perspective of preservation, it is **always** much more desirable to protect and manage (if necessary) the existing habitats of rare and endangered species. Transplanting is only to be considered as a last resort, when other more desirable options are impossible.

6. *Evaluation of Risks Associated with Peat Extraction from Swaine's Road Bog to* D. filiformis *in Nova Scotia.*

a) *Direct, On-site Risks.* Site preparation of the proposed peat-harvesting site on Swaine's Road Bog would require the destruction of pre-existing vegetation. *Drosera filiformis* is present within this site, and these individuals would all be killed, unless an effort was made to rescue them and transplant them elsewhere.

b) *Risks in the Near-field.* For the purposes of our study, the near-field spatial range was estimated to extend to several hundred meters from the boundary of the proposed peat-extraction site. The near-field could reasonably be anticipated to be incidentally disturbed or stressed by drawdowns of the watertable associated with harvesting and the planned ditching of the perimeter of the harvest site, an activity that is required to prevent excessive infiltration of water (Freedman et al. 1991).

In our opinion, a near-field hydrologic risk of the proposed peat harvesting and water-control procedures would be slow decreases in height of the water table, occurring gradually over the years. If this were to occur, an increased growth of shrubs and other species would intensify competitive stresses experienced by *D. filiformis* and this, along with water stress due to drying of its substrate, could eventually eliminate it from the plant community.

There are other views about the likely consequences of peat harvesting and ditching of a portion of a raised bog, on the hydrologic characteristics of nearby, unharvested and unditched portions (Technopeat 1984; Anderson and Broughm 1988). These views focus on the observation that, in the short- to medium-term, the drainage of rainwater and meltwater from upland bogs occurs almost entirely through a surface-superficial acrotelm or "active zone" of relatively poorly humified peat (Damman and Dowhan 1981; Johnson 1985; Stewart and Lance 1983, 1991; Coulson et al. 1990). This surface drainage occurs because the deeper, well-humified peat of plateau bogs has a small hydraulic conductivity, a very large absorptive capacity, and a small permeability to vertical water flow on the shorter- to medium-term (Radforth 1973; Walmsley 1973; Johnson 1985; Stewart and Lance 1983, 1991).

In spite of this inherent, water-level retention capacity of plateau bogs, we predict that over the longer-term any significant lowering of elevation of a large portion of a bog by harvesting and ditching will eventually lead to a change of the watertable throughout. This view is supported by certain operational practices in which drainage has been successfully applied to bogs and other peatlands in the pursuit of "improvements" in land capability for agriculture and forestry (Payandeh 1973; Stanek 1977; Johnson 1985; Robinson 1986; Haavisto and Wearn 1987; Hillman 1987; Toth and Gillard 1988; Anonymous 1989; Dang and Leiffers 1989; Jeglum 1990; Berry 1991). In one study done in coastal Georgia, drainage in combination with burning and grazing by livestock, was blamed for the extinction of *Drosera filiformis* and other rare species from a number of bogs (Pullen and Plummer 1964).

The temporal framework for the preservation of rare and endangered species is, of course, the longer term. As a result, we concluded that the integrity of the population of *D. filiformis* in the near-field could be compromised by indirect effects of activities occurring on the peat-extraction site.

c) *Risks in the Far-field.* The far-field spatial range for potential, longer-term, environmental influences of peat-extraction activities was estimated to extend up to several kilometers from the harvesting site. In terms of environmental effect, the most important physical linkage with the harvested area would be through changes in hydrologic regime, in particular drawdown of the watertable caused by hydrologic control of the peat mine. Following from the discussion above, it is our opinion that slow decreases in height of the water table could occur over the longer-term in the far-field spatial range, but the effects would probably be much smaller than in the near-field.

d) *Cumulative Risks of Peat Mining.* There are preliminary plans for a more-extensive extraction of peat from Swaine's Road Bog that would follow an economically and technologically successful implementation of the proposed, limited-area, pilot project. Moreover, suggestions have been made for the mining of fuel peat more extensively in Nova Scotia, and comprehensive peatland inventories have been prepared (Anderson and Broughm 1988). It is important to consider the potential, cumulative effects of these other, reasonably anticipated projects on the integrity of *D. filiformis* in Nova Scotia.

It is reasonable to expect that a successful implementation of the pilot extraction of fuel peat would effectively legitimize the harvest of peat from elsewhere on Swaine's Road Bog, presumably until the economic resource is exhausted. This would, of course, doom the population of *Drosera filiformis* that now exists in that wetland.

Another fairly large population of *D. filiformis* occurs at Port Latour Bog. This site is part of the same hydrologic complex as Swaine's Road Bog, but we believe that the Port Latour site is sufficiently far away (*ca.* 8 km) that it is unlikely to be at risk from indirect effects of the proposed peat mine. Another relatively large, inland population of *D. filiformis* occurs at Quinn's Meadow Bog, which is not hydrologically connected with Swaine's Road Bog. The fourth known population of *D. filiformis* at Baccaro Bog is only present in a small portion of that plateau-bog complex, and its small size may render it threatened over the longer term in the absence of protection and active management. None of these sites are threatened by the peat-mine proposal for Swaine's Road Bog, but of course in the absence of protection their populations of *D. filiformis* are threatened by future proposals to mine their own peat resource.

7. *Mitigation, Monitoring, and Other Actions to Decrease Risks.*

Potential effects on preservation, conservation, and other ecological values are only one element (albeit an important one) of the spectrum of potential environmental conflicts that arise when proposals are made to harvest natural resources. In the pursuit of economic development and other social goals, resource-exploitation schemes may be allowed to proceed at some level of ecological detriment that is deemed to be "acceptable" by decision-makers. In view of this fact, it is prudent to consider mitigative and monitoring activities that could be implemented to decrease risks to the integrity of *D. filiformis* in Nova Scotia, in the event that peat mining is allowed at Swaine's Road Bog.

a) *Transplantation.* If peat mining from a site occupied by *D. filiformis* is permitted, then consideration should be given to mounting a rescue of the plants at risk. These would most preferably be collected in early autumn and transplanted either to: (i) nearby sites which are not known to have *D. filiformis*, but that appear to provide acceptable habitat, or (ii) other known sites of occurrence.

However, there are great risks with transplantation. Even though it appears that *D. filiformis* is relatively easy to propagate and transplant, the longer-term persistence of any population of a rare and endangered species introduced to a new habitat cannot be predicted. In preservation, the only measure of a successfully transplanted population is viability for a very long time. As a result, Canadian botanists have taken strong stands against the transplantation of rare and endangered plants, in favour of preserving their natural habitat (Fahselt 1988; CBA 1991).

b) *Monitoring of Hydrology and* Drosera filiformis *at Swaine's Road Bog.* The most contentious issue regarding the effects on *D. filiformis* of the pilot proposal to mine peat concern potential hydrologic effects in the near-field and beyond. If the proposed mining was permitted, then a monitoring program should be in place to determine reasonably anticipated hydrologic effects, and any changes in the abundance or vigor of *D. filiformis* in near-field and perhaps far-field locations. If significantly detrimental effects are observed through monitoring, then consideration could be made for application of appropriate mitigation or restorative actions.

Indicators appropriate for monitoring include: (i) height of the bogwater table at sampling wells situated at various distances from the proposed mine site, and (ii) abundance and vigor of individuals of *D. filiformis* in permanent quadrats, also located at various distances from the mine site. Important in design of the monitoring program would be the inclusion of reference sites beyond the reasonably anticipated influence of the pilot project. Preferably, the monitoring would be carried out by qualified persons operating independently of the peat-mine.

c) *Creation of Ecological Reserves at Other Known Locations of* Drosera filiformis *in Nova Scotia.* Ecological reserves should be established to protect as many as possible of the sites of *D. filiformis* in Nova Scotia. This need is already acute, and it would be further heightened if permission were granted to mine peat from Swaine's Road Bog. Without effective protection of the alternate, most-viable sites at Port Latour Bog and Quinn's Meadow Bog, the longer-term integrity of *D. filiformis* in Nova Scotia, and Canada, would be severely threatened.

d) *Development of a Strategy for Preservation of the Coastal Plain Flora.* Because of its special ecological legacy of sites with rare coastal-plain plants, Nova Scotia should have a comprehensive strategy in place for the sustainable protection of the habitat of this flora. Specific strategies for protection of the habitat of *Drosera filiformis* should be integrated within that broader provincial policy, once it is developed.

8. *Overview and Resolution.*

There are only three known, high-quality sites and populations of *Drosera filiformis* in Canada. One of the best of these sites (Swaine's Road Bog) is threatened by a proposal to mine fuel peat. Furthermore, all of the sites of *D. filiformis* in Nova Scotia are potentially threatened by future proposals for similar peat-mine developments.

In December of 1991, the Nova Scotia Minister of the Environment refused to allow the proposed peat mine at Swaine's Road Bog to proceed. The stated rationale was the risks to the integrity of *Drosera filiformis* in Nova Scotia, as discussed in the impact assessment (summarized here) for Nova Scotia Department of the Environment (NSDOE). In an accompanying press release, NSDOE noted that they had offered to assist the proponent in finding another nearby bog for mining that does not have a population of *D. filiformis*, and they stated an intention to set up an ecological reserve at Swaine's Road Bog. This is a rare example in which consideration for the integrity of a rare and endangered species of plant has halted a proposed resource development in Canada or elsewhere.

Following from the minister's decision, the proponent's only recourse as far as the Swaine's Road site is concerned is to undertake a full environmental assessment of the proposed peat mine. Such an assessment would examine the full spectrum of other potential environmental impacts, including re-evaluation of the already well-recognized risks to *D. filiformis*. It remains to be seen whether this expensive pathway will be pursued, or another less sensitive site will be sought for mining.

Acknowledgments

This work was funded by the Nova Scotia Department of the Environment. We are grateful to David MacKinnon, Patricia Manuel, Martin Willison, and three anonymous referees for their critical comments on drafts of the manuscript.

Literature Cited

Anderson, A. R. and **W. A. Broughm.** 1988. Evaluation of Nova Scotia's Peatland Resources. Bulletin 6, Nova Scotia Department of Mines and Energy, Halifax.

Anonymous. 1989. Draining forest land: A literature review. Forest Research Report Number 11, Nova Scotia Department of Lands and Forests, Truro.

Anonymous. 1990. The Nature Conservancy Heritage Database: Rare Plants. Division of Endangered Species and Habitat Conservation, United States Fish and Wildlife Service, Bethesda, Maryland.

Anrep, A. 1915. Investigation of the peat bogs and peat industry in Canada 1913-1914. Canada Department of Mines, Ottawa.

Argus, G. and **K. Pryer.** 1990. Rare vascular plants in Canada: Our natural heritage. Botany Section, Canadian Museum of Nature, Ottawa.

Beals, E. 1960. Forest bird communities in the Apostle Islands, Wisconsin. Wilson Bulletin 72: 156-181.

Berry, G. J. 1991. Hydrology of drained and undrained Black Spruce peatlands: Streamflow and hydrologic balance. COFRDA Report 3317, Great Lakes Forest Research Center, Sault Ste. Marie, Ontario.

Bousfield, E. L. and **M. L. Thomas.** 1975. Postglacial changes in the distribution of littoral marine invertebrates in the Canadian Atlantic region. Proceedings of the Nova Scotia Institute of Science 27 (supplement 3), 47–60.

CBA. 1991. Transplantation as a means of preservation. Conservation Position Paper Number 1, Canadian Botanical Association, Ottawa.

COSEWIC. 1991. Notes and definitions on the status of endangered wildlife. Committee on the Status of Endangered Wildlife in Canada. Canadian Museum of Nature, Ottawa.

Coulson, J. C. and **J. E. L. Butterfield.** 1990. The effect of open drainage ditches on the plant and invertebrate communities of moorland and on the decomposition of peat. Journal of Applied Ecology 27: 549–561.

Damman, A. W. H. and **J. J. Dowhan.** 1981. Vegetation and habitat conditions in Western Head Bog, a southern Nova Scotia plateau bog. Canadian Journal of Botany 59: 1343-1359.

Dang, Q. L. and **V. J. Lieffers.** 1989. Assessment of patterns of response of tree ring growth of Black Spruce following peatland drainage. Canadian Journal of Forestry Research 19: 924–929.

Fahselt, D. 1988. The dangers of transplantation as a conservation technique. Natural Areas Journal, 8: 238–244.

Fernald, M. L. 1918. The geographic affinities of the vascular floras of New England, the Maritime Provinces, and Newfoundland. American Journal of Botan 5: 219–239.

Freedman, B. 1989. Environmental Ecology. Academic Press, San Diego.

Freedman, B., J. Kerekes, and **G. Howell.** 1989. Patterns of water chemistry among twenty-seven oligotrophic lakes in Kejimkujik National Park, Nova Scotia. Water, Air, and Soil Pollution 46: 119–130.

Freedman, B., W. Maass, and **P. Parfenov.** 1991. Assessment of the likely effects of peat extraction from Swaine's Road (Barrington) Bog, Shelburne County, on *Drosera filiformis* and its habitat. Report to Nova Scotia Department of the Environment. Department of Biology and School for Resource and Environmental Studies, Dalhousie University, Halifax.

Gleason, H. A. 1952. The New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada. Hafner Press, New York.

Haavisto, V. F. and **V. H. Wearn.** 1987. Intensifying forestry use of peatlands with drainage in Ontario. Pages 249-256 *in* Proceedings Symposium '87 Wetlands/Peatlands. *Edited by* C. D. A. Rubec and R. P. Overend, Canadian Forestry Service, Edmonton.

Hill, N. M. and **M. Zinck.** 1990. Preliminary report on the effect of peat mining on Swaines Bog vegetation. Nova Scotia Museum, Halifax.

Hillman, G. R. 1987. Improving wetlands for forestry in Canada. Information Report NOR-X-288, Northern Forestry Center, Edmonton.

Jeglum, J. 1990. Peatland forestry in Canada: An overview. Pages 19-28 *in* Biomass Production and Element Fluxes in Forested Peatland Ecosystems. Swedish University of Agricultural Sciences, Umea, Sweden.

Johnson, C. W. 1985. Bogs of the Northeast. University Press of New England, Hanover, New Hampshire.

Juniper, B. E., R. J. Robins, and **D. M. Joel.** 1989. The Carnivorous Plants. Academic Press, San Diego.

Keddy, P. A. 1979. Endangered wild plants of Nova Scotia. Nova Scotia Conservation 3: 5–12.

Keddy, P. A. 1985. Lakeshores in the Tusket River Valley, Nova Scotia: the distribution and status of some

rare species, including *Coreopsis rosea* Nutt. and *Sabatia kennedyana* Fern. Rhodora 87: 309–320.

Larsen, J. A. 1982. Ecology of the Northern Lowland Bogs and Conifer Forests. Academic Press, San Diego.

Lecoufle, M. 1991. Carnivorous Plants: Care and Cultivation. Sterling Publishing Co., Blandford, U.K.

Lloyd, F. E. 1942. The Carnivorous Plants. Chronica Botanica Co., Massachusetts.

Maher, R. V., D. J. White, G. W. Argus, and **P. A. Keddy.** 1978. The rare vascular plants of Nova Scotia. Syllogeus Number 18. National Museums of Canada Ottawa.

Payandeh, B. 1973. Analyses of a forest drainage experiment in northern Ontario. Canadian Journal of Forest Research 3: 387-398.

Pullen, T. and **G. L. Plummer.** 1964. Floristic changes within pitcher plant habitats in Georgia. Rhodora 66: 375–381.

Radforth, N. W. 1973. Muskeg hydrology. Pages 131-147 *in* Muskeg and the Northern Environment of Canada. National Research Council, Ottawa.

Robinson, M. 1986. Changes in catchment runoff following drainage and afforestation. Journal of Hydrology 86: 71–84.

Roland, A. E. 1982. Geological Background and Physiography of Nova Scotia. Nova Scotia Institute of Science, Halifax.

Roland, A. E. and **E. C. Smith.** 1969. The Flora of Nova Scotia. Nova Scotia Museum, Halifax.

Schwartz, R. 1975. Carnivorous Plants. Avon Books, New York.

Stanek, W. 1977. Ontario clay belt peatlands - are they suitable for drainage? Canadian Journal of Forestry Research 7: 656–665.

Stewart, A. J. A. and **A. N. Lance.** 1983. Moor-draining; a review of impacts on land use. Journal of Environmental Management 17: 81–99.

Stewart, A. J. A. and **A. N. Lance.** 1991. Effects of moor-draining on the hydrology and vegetation of Northern Pennine blanket bog. Journal of Applied Ecology 28: 1105–1117.

Tarnocai, C. 1984. Peat Resources of Canada. National Research Council, Ottawa.

Technopeat, Inc. 1984. Feasibility study to determine the potential of fuel peat for an industrial utilization in southwestern Nova Scotia. Prepared for Nova Scotia Department of Mines and Energy by Technopeat, Inc. Halifax.

Toth, J. and **D. Gillard.** 1988. Experimental design and evaluation of a peatland drainage system for forestry by optimization of synthetic hydrographs. Canadian Journal of Forestry Research 18: 353-373.

Walmsley, M. E. 1973. Physical and chemical properties of peat. Pages 83-129 *in* Muskeg and the Northern Environment of Canada. National Research Council, Ottawa.

Winkler, M. G. and **C. B. DeWitt.** 1985. Environmental impacts of peat mining in the United States: documentation for wetland conservation. Environmental Conservation 12: 317-330.

Wynne, F. E. 1944. *Drosera* in eastern North America. Bulletin Torrey Botany Club 71: 166-174.

Zinck, M. 1991. Status Report on the Thread-leaved Sundew, *Drosera filiformis* Raf. Committee on the Status of Endangered Wildlife in Canada. Canadian Museum of Nature, Ottawa.

Received 10 February 1992
Accepted 1 April 1993

Book Reviews

ZOOLOGY

Mule Deer Country

By Valerius Geist, Photography by Michael H. Francis. Northword Press, Minocqua, Wisconsin. 176 pp. illus. U.S. $39.

Anyone with an interest in wildlife will be delighted with this coffee-table book that offers textual substance as well as the usual photographic orientation. Dr. Geist, the world's foremost authority on mule deer shares with readers the results of research conducted since 1969 with the focus primarily on the animal's behaviour.

The book begins by liberally delving into the evolution of deer species. Researchers have determined that the mule deer descended from white-tailed deer mothers and black-tailed deer fathers. This subject is explored with detailed coverage from the results of DNA studies.

The bulk of the text, with five of the eight chapters, is designed to acquaint the reader with different aspects of mule deer behaviour from surviving predators to mating rituals. Dr. Geist's expertise in ethology is evident as he explores various subject matters, among which are anti-predator strategies, rank and power in mule deer society, and methods of general survival.

Much of the text offers comparisons between mule deer and white-tailed deer behaviour. Where white-tails will sprint away from danger and head down slope, mule deer will engage in high jumps and "stott" up a slope. The analysis of various behavioural characteristics of both species is extensive and one cannot help but become absorbed in the author's observations and explanations.

The close-up colour photography by Michael Francis beautifully complements the text. Mule deer are shown in natural settings blithely unaware of human presence. This is a trademark of a good photographer and one that Francis has obviously mastered. Many of the pictures give readers a glimpse of the private life of the deer as they are sparring, horning, mating, or quietly feeding in groups. There are also included photo sequences that further serve to demonstrate the behaviours being discussed.

The combined efforts of Geist and Francis succeed in providing well-rounded coverage of the natural history of the mule deer. The extent of field research and experimental study is evident and both should be commended for their contribution to broadening our understanding of a sometimes elusive species.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario K0A 2W0

The Natural History of Moles

By Martyn L. Gorman and R. David Stone. 1990. Cornell University Press, Ithaca, New York. xiv + 138 pp., illus. U.S. $27.50.

The Natural History of Mammals Series, covering antelope, deer, weasels, squirrels, and other groups, is a significant contribution to the mammal literature. Each edition gives professionals and amateurs ready access to current scientific information usually squirrelled away in journals and theses. *The Natural History of Moles* maintains the high standard of the series. It is an intriguing and enthusiastic overview of a mammal taxon which also gives a good introduction to the basic questions and issues in mammalogy.

Gorman and Stone examine both the mole family Talpidae and the golden mole family Chrysochloridae (of southern Africa). Talpids called desmans, which resemble miniature platypus, warranted a separate chapter because of their aquatic nature. The text is mostly undaunting; few specialized terms stand without benefit of a definition. The authors intersperse their scientific queries with anecdotes and assorted mole-catcher lore and legend. The text is effectively supported by abundant diagrams, figures and line drawings. Twenty colour plates depict mole portraits, biology, and natural history. Appendices deal with keeping moles in captivity and with ectoparasites.

The patterns and energy dynamics of digging for a living were given an entire chapter, as were the standard topics of feeding, life cycles, and behaviour. Gorman and Stone leave species descriptions and measurements for taxonomy texts. Canadians are lucky that the National Museum's *Handbook of Canadian Mammals* at least reached moles and shrews before publication of C.G. Van Zyll de Jong's valued series ground to a halt.

This book has much to offer the curious naturalist. I found mole relations with earthworms particularly interesting. Heads are nipped off and the bodies stored in suspended animation for future feeding. Worms are squeezed like toothpaste tubes to rid the body cavities of soil before eating. Moles have never been a threat to my property or livelihood, so I was unprepared for the chamber of horrors depicted in the chapter: "Getting rid of a surfeit of moles." I swear only the guillotine remains to be adapted for mole trapping.

This is one mammalogy reference that can also be read cover to cover, if you are so inclined. It is succinct, stimulating and well-written. *The Natural History of Moles* will satisfy the technical needs and general curiosity of naturalists, biologists, and students. The science of mammalogy and the growing numbers of amateurs interested in mammals will both benefit from this informative book.

Mark Stabb

R.R. 6, Renfrew, Ontario K7V 3Z9

The Great Bear: Contemporary Writings on the Grizzly

Edited by John A. Murray. 1992. Alaska Northwest Books, Bothell, Washington. 248 pp. U.S. $14.95, Canada $18.95.

Concern for a greater understanding and conservation of the Grizzly Bear and its habitat has been expressed for more that half a century. During the past two decades, this concern has intensified and become one of the most popularized environmental issues faced by wildlife managers. The grizzly was officially recognized as a threatened species in the 48 contiguous states in 1973. Once distributed throughout the Rockies, Sierras, and western Great Plains, the grizzly currently occupies a small fraction of its historic range south of Canada, numbering no more than 1000 individuals.

Murray, a professor at the University of Alaska and author of numerous nature books, has compiled a series of essays about the grizzly written after Aldo Leopold's seminal 1949 essay "Escudilla". The objectives of this book were two-fold; to materially assist The Nature Conservancy in its efforts to acquire grizzly bear habitat by donating royalties from the book to their Pine Butte Swamp Grizzly Bear Preserve near Choteau, Montana, and to publish under one cover a series of contemporary writings about the species, otherwise poorly accessible. Although I question whether financial gain should be the primary motive for writing any book, irrespective of use, Murray has undoubtedly met his second objective.

This anthology contains 17 chapters, divided into four political or geographic regions: Alaska, the northern Rockies, Yellowstone National Park, and the Southwest. An excellent attribute of the book is that each essay is prefaced with a brief description of the author and an overview of the chapter's content. Most valuable is that Murray extracts from each essay one or more key statements that lend cohesion and provide an overall theme for the book; one unequivocally supporting grizzly conservation.

Individual accounts range from excerpts of the Craighead's pioneering radio telemetry studies to Doug Peacock's cross-country adventure over the Continental Divide. Additional chapters contain the writings of well-known authors such as Edward Abbey, Aldo Leopold, Thomas McNamee, John McPhee, and Adolf Murie. Murray is to be commended for his selection of essays. Although individual authors' backgrounds, experiences, and approaches varied markedly, all shared similar interests and common goals in their respect and admiration for, and dedication to, the conservation of one of North America's most magnificent carnivores.

Also included are figures of Alaska and the lower 48 states that describe the historic and present range of the grizzly, potential reintroduction sites, and locations where each account took place. Following the essays are an epilogue which aids nicely in unifying individual chapters, a chronology of historical and recent events concerning grizzly management and conservation, a list of suggested references for further reading, and an index.

Although I found this book to be entertaining and enlightening, it was simultaneously depressing. Grizzly Bears are in no danger of extinction; however, one cannot help thinking about situations where the outcome for species survival is less encouraging; e.g., California Condor, Black-footed Ferret. Murray attempts to rekindle awareness and public support for the grizzly in an effort to circumvent what has happened to other species at alarming rates innumerable times. I recommend this book to individuals with an interest in species conservation and wilderness; those who desire a scientifically intense account of the grizzly will be disappointed

JERROLD L. BELANT

U.S. Department of Agriculture, Denver Wildlife Research Centre, 6100 Columbus Avenue, Sandusky, Ohio 44870

Present address: Great Lakes Indian Fish and Wildlife Commission, 1908 1/2 West Superior Street, Duluth Minnesota 55806

Peterson First Guide to Reptiles and Amphibians

By Roger Conant, Robert C. Stebbins, and Joseph T. Collins. 1992. Houghton Mifflin Company, Boston. 128 pages + illus. U.S. $4.95.

The adult Peterson field guide series remains a continuing tribute to the good instincts of the Houghton Mifflin editor who, in 1934, took a chance on a young artist with a flair for accuracy in both painting and writing and a new approach to field identification. Each contribution to the series that resulted has become an instant standard for the naturalist industry. In recent years an unsatisfied niche was perceived between the realization of the wonder of variation in the natural world and the maturity to read through a comprehensive field guide. The *First Guide* series is for this niche, applied first to birds and now extended to amphibians and reptiles.

This book is a selection of illustrations from the most recent editions of the western (by Stebbins) and eastern (by Conant and Collins - see review in *The Canadian Field Naturalist* 105(4): 608–610) comprehensive guides. It is amazing to see how well the two very different illustrative techniques (paintings by Robert C. Stebbins in the western, and hand-coloured photographs by Isabelle Hunt Conant and Tom R. Johnson in the eastern) have blended - many plates have eastern and western forms side-by-side with little visible clash. The simpler format of only three or four forms a page has allowed reproduction at a larger size than in the more crowded plates of the detailed parent guides and heightened the realization of just how fine these illustrations really are. The Mink Frog is a particularly outstanding example.

This *First Guide*, aside from some very cursory introductory material, is primarily picture-focused with a plate (usually in colour but with a few adequate black-and-whites: 1 representative tadpole, 4 turtles, 7 lizards, and one view of a snake) on every right hand page with text on the left, opposite each form depicted. There are no range maps. The brief write-ups are accurate enough to highlight selected features. The condensed format has neccessitated ultra "lumping", however, and only 182 forms were chosen to represent these classes for the entire continent. Total omission of scientific names facilitates sidestepping problems of definition of species or subspecies units within complexes. Because the selection is primarily of wide-spread species, Canadians are disproportionately well-served with 39 of our 43 native amphibians and 34 of our 42 reptiles presented, mostly in variations recognizable here.

The size is conveniently thin, narrow, and pocket-orientated so it can be taken along on the most casual outing. Any child with a snake or frog in one pocket should be given a copy of this book for the other. An appetite for more detailed information should soon follow.

FRANCIS R. COOK

Canadian Museum of Nature, Ottawa, Ontario K1P 6P4

A Guide to Feeding Winter Birds in Ontario

By Bob Waldon. 1991. Whitecap Books, Vancouver /Toronto. xiii + 222 pp., illus. $15.95.

This is the best and most comprehensive guide to winter bird feeding yet. Even if you have fed winter birds for 20 years, you will find new information and plenty of ingenious ideas to improve your techniques. If you are a novice, this will be your best reference book.

The information is presented in a lucid and lively way - even the section on the lowly pigeon family is fresh and interesting. As well as chapters on feeds, seeds, shelters, and feeders, each of the 55 species normally found during an eastern Canadian winter are described, with their behaviour, range, food preference, nest, and shelter. One novel touch is an explanation of the roots of the Latin and the common name. For example the Titmouse. The word originated from the Norse tittre = small or little, and Anglo-Saxon mase or mose = small bird. The plural should be titmouses! "The Down Side" chapter, or how to outwit predators, will delight all would-be assassins of squirrels/cats.

A useful appendix lists the address and telephone number of every naturalist club and agency in Ontario. This is the only Ontario-specific section, and all the other information is applicable to central and eastern Canada.

The drawings by Peter Sawatsky match the text and production in excellence. A recommended addition to your library.

JANE E. ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T5

The Avian Ark: Tales from a Wild Bird Hospital

By Kit Chubb. Western Producer Prairie Books, Saskatchewan. 157 pp. illus. $22.95.

Many people lead interesting lives, some more than others. Often one hears of someone involved in a unique profession. This is one such story by one such person. Kit Chubb developed a love of natural history in her early childhood. As an adult she became a nurse by profession. It is her twelve years nursing experience and an interest in biology that gave her the background for her present occupation, a self-taught rehabilitator of wild birds.

The Avian Care and Research Foundation located in Verona, Ontario, was founded in 1978 by Kit Chubb and her husband Robin. In 1976 while being introduced to the art of mist-netting and banding birds, a wood warbler was injured. Mrs. Chubb brought the bird home in an attempt to find medical attention. The problem was there was only one facility that could treat the bird, the Owl Rehabilitation and Research Foundation in St. Catherines. It was then the idea of a bird hospital was launched. Since that time the Chubbs' lives have never been the same.

The Avian Ark is a compendium of short stories and delightful accounts of the many challenging patients the centre has treated over the years. The book is broken down into twelve chapters addressing various bird families. One will become acquainted with behaviour and idiosyncrasies of hawks, vultures, ducks, and owls who have at one time or another made the hospital their home.

The reader will be introduced to Yik, an eleven-year resident rough-legged hawk, Left and Right the infant Red-tails, and Wowl the Great Horned Owl. Eagles on the freezer and pelicans in the bathtub are not unusual occurrences in the Chubb household. With the prose of a gifted storyteller, the author will continually entertain you and make you laugh. Other times she will stir your emotions as she recounts not only the successes but the heart-breaking losses.

In addition to her expertise as a rehabilitator, Mrs. Chubb possesses artistic talents as well. Throughout the book one will find numerous black-and-white illustrations by the author who pays particular attention to fine details.

The Avian Ark is a captivating and enjoyable account of the workings of a wild-bird hospital and the dedication of the people who make it possible. It is highly recommended as a light, yet informative read.

JO-ANNE MARY BENSON

Box 265, Osgoode, Ontario K0A 2W0

ENVIRONMENT

Wild Animals and American Environment Ethics

By Lisa Mighetto. 1991. University of Arizona Press, Tucson. xii + 176 pp., illus. Cloth U.S. $35; paper U.S. $17.95.

Who's afraid of the big bad wolf? Or, more to the point, why are we afraid of the big bad wolf in the first place? Human perceptions of wild animals have gone through enormous oscillations that have far more to do with human thought processes and cultural development than with the actual attributes of the animals themselves. In a well referenced, scholarly, yet eminently readable account, Lisa Mighetto has chronicled the evolution of attitudes towards animals in the United States, as portrayed in American popular literature, since the end of the nineteenth century, and has examined how early treatises on animals set the stage for the development of a more comprehensive modern American environmental ethic.

Though concern for animal welfare has a long written tradition dating back to the ancient Greek philosophers, the shift from a more utilitarian perspective did not occur in the American popular conscience until the late 1800s. Mighetto identifies the past century as the period of the most rapid change in terms of interest, appreciation, and conservation of wild animals in America. In the past hundred years, she maintains, increasing urbanization has resulted in ever-larger populations of city dwellers who are far removed from the processes of the natural world, and can afford to "romanticize and cherish wildlife" to a far greater degree than their rural and agricultural counterparts.

Concomitant with the migration from farm to factory was an explosion of interest in, and discussion of, animal welfare and rights. In the chiaroscuro of recently-emerging Darwinian theory, the place of humankind within the natural order was thrown open to interpretation and debate, challenging the traditional views of church and state. It was within this historical context that essayists such as John Muir and John Burroughs sought to redefine the role of humans within nature, and eloquently advanced arguments for

the conservation of wildlife and the protection of the natural environment. Popular authors such as Ernest Thompson Seton, Sir Charles G. D. Roberts, and Jack London wrote highly anthropomorphic fictional and semi-fictional narrative accounts of wild animals, infusing the popular conscience with accounts of animal heroism, loyalty, cruelty, and morality. Pioneering American conservationists such as Theodore Roosevelt, William T. Hornaday, and George Bird Grinnell worked to entrench principles of husbandry and stewardship amongst hunters and fishers. Later, scientists such as Aldo Leopold and Olaus and Adolph Murie applied scientific principles to the art of wildlife management.

Gradually, the foundations of American environmental ethics became discernible. The early exhortations of Liberty H. Bailey and John Muir against the abuse of the natural world amplified upon the concerns of the humanitarian movement, but extended ethical responsibility from concern for individual animals to concern for nature as a whole. Mighetto does a thorough job of recording the shift in attitude from anthropocentric utilitarianism, through humanitarianism, to biocentrism. She documents the major American chroniclers of the emerging environmental ethic until the middle of the twentieth century. Philosophical stances such as those of Muir and Bailey were amplified upon by a coterie of subsequent authors, reinforcing the arguments for ecological integrity on moral and ethical grounds rather than solely on the basis of scientific pragmatism. By mid-century, a cogent "land ethic" had been distilled and formally articulated by Aldo Leopold, in the form of the iconic *A Sand County Almanac,* published posthumously in 1949.

Mighetto's scope is intentionally and forgivably restricted, concentrating upon American authors by design. As an historical overview of the evolution of American environmental ethics from the late 1800s to the middle of this century, this book succeeds wonderfully. But the treatment of the modern-day (i.e., post-Leopold) voices of environmental ethics is cursory. The first hundred pages of the book, including illustrations, are devoted to the period prior to 1950; a scant 21 pages (including epilogue!) give but a brief survey of environmental thinkers who have followed.

Also absent from Mighetto's analysis is any consideration of the influence of the non-print media on the evolution of environmental ethics. Though written works arguably capture the subtleties and nuances of philosophical persuasion more effectively and enduringly than other media, the influence of film and television upon attitudes towards animals and towards environmental ethics in general, cannot be underestimated. (Nor is their influence particularly recent: I would hazard that Walt Disney's *Bambi*, released in 1942, has had a greater impact upon *popular* sentiment about animals than all of the works of Leopold, Muir, and Burroughs combined!). Similarly, the role of television in the popularization and entrenchment of the modern environmental movement is immeasurably huge - it is doubtful that public concern over environmental issues would be nearly as great in the absence of T.V. news and nature documentary programs.

The flyleaf introduction to the book states, "Mighetto places arguments regarding wildlife protection in historical perspective and thus helps us evaluate our inherited attitudes and assumptions about the animal world". This is true (at least if we assume that the reader is an American with a primary interest in the evolution of western environmental ethics until the time of Aldo Leopold). A particular highlight of the book is the chapter "Working Out the Beast: American Perceptions of Predators", a telling synopsis of the ambiguities felt by the American populace towards carnivorous animals. But an important caveat is that recent (post-1950) environmental thought is explored only in sketchbook form.

As an environmental historian, Mighetto's forte is lucid chronicling, not critical analysis; those interested in a piercing dissection of western attitudes towards wildlife would do better to consult John Livingston's *The Fallacy of Wildlife Conservation.* But as a lively and readable historical overview of a significant era in the development of environmental thought in America, this book is to be recommended.

DAVID T. BROWN

Institute of Urban and Environmental Studies, Brock University, St. Catherines, Ontario L2S 3A1

Nature Reserves: Island Theory and Conservation Practice

By Craig L. Shafer. 1990. Smithsonian Institution Press, Washington, D.C. 08 pp., illus. Cloth U.S. $39.95; paper U.S. $15.95.

Given the rapid disappearance of natural lands and species in recent years, a book summarizing the concepts dealing with nature reserve design sounds like good news. Craig Shafer has taken on the job of summarizing the English literature dealing with island biogeography and its usefulness for nature reserve design and management. He has done an excellent job with a complex and diverse literature. His bibliography contains an impressive 28 pages of references.

Shafer explains the theory of island biogeography and each of its corollaries. For example, he discusses, at length, topics such as: species and area relationships, minimum viable populations, extinction biology, habitat size, isolation effects, and relaxation. For each he outlines the background concepts, the experimental data for various interpretations and attempts a summary of the scientific consensus on each interpretation.

This is the latest and most-up-to date book that summarizes the literature in this field. The author is very even handed in his treatment of the material. He goes out of his way to present all sides of an argument, even the very weak ones. As a result, one is left with the feeling that the give and take in the scientific debate has not resulted in many firm conclusions.

The author's goal is a "a discussion of the theoretical aspects of nature reserve size, isolation, and design, as well as planning and management implications". He concentrates on the literature surrounding island biogeography, as first proposed by MacArthur and Wilson in their 1967 landmark publication on the topic. He does this very well. His coverage and understanding of this literature is excellent. However, the planning and management implications are not well presented.

Upon the conclusion of the book, one feels a little lost, given the propensity to discuss the debate in all its facets and the hesitancy to state firm conclusions. After 140 pages of review of the literature the author concludes the critical design issues are: "reserve size, reserve numbers, distances between reserves, connectivity, location and the relationship between reserves, and surrounding lands and people". It seems hardly necessary to review hundreds of scientific papers to conclude this.

The author is strong on the scientific literature but weak on the planning literature. His understanding of environmental planning shows in a very feeble section, augustly entitled "Regional Planning in the World". It runs to part of a page and totally ignores environmental planning on private lands. The author is fixated on national parks and virtually ignores the environmental significance of other public land uses such as wildlife refuges, managed forests, and reservoir sites.

Given the many problems with attempting to implement a general theory of reserve design, the author mentions, near the end of the book, the importance of species-specific studies and management. However, he then ignores the world's largest effort in species specific habitat selection and conservation, the natural heritage program operated by the U.S. Nature Conservancy. The book also gives short shrift to the landscape ecology and conservation biology literature.

The book is an excellent review of the island biogeography literature. It should be read by anyone who wishes to bring themselves up to speed on that literature to the year 1988. For the environmental planner who wishes to use it for hints on nature reserve design and management, the book isn't much use. It is a long treatise stating that the scientific community has not been able to prove that most theories of island biogeography are valid or how they can be used. After reading the book, I am left with the impression that the author has concluded that the scientists are fiddling while nature is burning.

PAUL F.J. EAGLES

Department of Recreation and Leisure Studies, University of Waterloo, Waterloo, Ontario N2L 3G1

MISCELLANEOUS

Women in the Field: America's Pioneering Women Naturalists

By Marcia Myers Bonta. 1991. Texas A&M University Press, College Station. xix + 299 pp., illus. Cloth U.S. $29.50; paper U.S. $13.95.

Until the last decade or so, the accomplishments of most women naturalists were excluded from histories of natural history. While many of them were known to their contemporaries, the following generations often considered them as marginal to discoveries, mere assistants to male naturalists. Only Margaret Morse Nice and Rachel Carson became known to a variety of people, scientists, and the general public but, in the 1990s, who has ever heard of Kate Furbish, Cornelia Stanwood, or Carrie Dorman?

In *Women in the Field: America's Pioneering Women Naturalists* Marcia Bonta sets out to rectify the record. Researched over several years by one of America's finest contemporary nature writers, the 25 biographies encompass two centuries.

The book is divided into six sections: The Pioneers; The Naturalists; The Botanists; The Entomologists; The Ornithologists; and The Ecologists. Each section begins with an introduction which sets the context for the individual biographies in that section. These introductions include brief notes on, or mentions of, other naturalists - both men and women - whose life and work

was influential in the relevant period and discipline.

The grouping of the biographies in "pioneers," "naturalists," or "entomologists" is quite arbitrary. Graceanna Lewis was a pioneering ornithologist, yet she is in the naturalists section; "Edith Patch Entomological Naturalist" is in entomology, while Florence Merriam Bailey is referred to as "First Lady of Ornithology," a subtitle that should have gone to Lewis.

The actual biographies are written in the lively colourful style Bonta has used in her articles in the *Bird Watcher's Digest, American Horticulturist,* and *Quaker History.* They contain much fascinating information, and wonderful insights into interesting personalities. As such they will appeal to the general reader as well as to specialists interested in a well balanced history of American naturalists. The black-and-white illustrations greatly enhance this attractive book.

Unfortunately, there is a discrepancy between the carefully researched and well-written biographies and some of the chapter titles, e.g. "Maria Martin. Audubon's Sweetheart", "Amelia Laskey. Patron Saint of the Birds", or "Carrie Dorman. Queen of the Forest Kingdom." Because of the high quality of Bonta's nature writing, one wonders whether or not editorial policy and lack of proper copy editing are at fault. Instances of sloppy copy-editing are evident throughout the text. What is a golden-throated vireo (p.188)? The name is not even in quotation marks. The same is true of russet-backed thrush (p. 194), and Sennett's hawk (p. 192). Cassin sparrow (p. 191) should be Cassin's sparrow, as the name is spelled when referring to Cassin's finch (p. 193). And if Florence Merriam Bailey deserves a chapter of her own, (and there is a full biography by Harriet Kofalk) why refer to her as Vernon Bailey's wife in another chapter?

Nitpicking? Perhaps, but naturalists have long specialized in observing and documenting fine differences.

Despite these caveats, I welcome the book as a useful addition to the growing literature on women scientists. It is highly readable, reasonably priced, and suitable for all ages.

MARIANNE GOSZTONYI AINLEY

4828 Wilson Avenue, Montreal, Quebec H3X 3P2

Queen's Biology: An Academic History of Innocence Lost and Fame Gained 1858-1965

By B.N. Smallman, H.M. Good, and A.S. West. 1991. Department of Biology, Queen's University, Kingston, Ontario. xiv + 215 pp., illus.

Histories of university departments are unlikely to be crowd-pleasers. But this attractively-produced, engagingly-written, thoughtful book about one of Canada's best natural science departments deserves a wide audience. Historians, scientists, science policy-makers, sociologist of science, and general readers can find much of interest in the tale of how a minuscule teaching department in a small Ontario university found itself in the big time in the late twentieth century.

A university is not the ivory tower, isolated from the society it serves and mirrors that urban mythology would have us believe. By concentrating on short biographies in a university setting, the authors show how the varied personalities and careers of Queen's biologists contributed, first, to a teaching institution and, later, to a department in which research became an equal or greater goal. The career of the distinguished Scot George Lawson, appointed in 1858, James Fowler and his herbarium, the aggressive, energetic A.P. Knight's influence on medical education and marine research, W.T. MacClement's organization of the famous Summer School, R.O. Earl's humanistic devotion to teaching, the influence of the department's field station at Lake Opinicon, and the evolution of a modern academic department, are important parts of the story of Queen's and of Ontario's history. They are described in mini-essays with grace, style, and wit. A self-congratulatory Epilogue by a recent Department head and his associate brings the account into the 1990s, although the book deals most deeply—and most effectively—with the period from about 1860 to the 1950s.

Flesh and blood make history. Too few accounts of scientific institutions retain the vitality of the actors who made that history. Smallman, Good, and West may be proud of a book that makes the a past of Queen's Biology come alive and that skillfully converts the small change of day-to-day university affairs into the larger currency of good historical writing.

ERIC L. MILLS

Department of Oceanography, Dalhousie University, Halifax, Nova Scotia B3H 4J1

Anton Dohrn: A Life for Science

By Theodor Heuss. 1991. Springer, New York. xxxvi + 401 pp., illus. U.S. $50.

At the historical head of all the many aquaria and field stations which now cover the globe stands the Naples Zoological Station which opened in 1873. The present book is a translation of a biography of its founder who lived from 1840 to 1909. Dohrn's background included a wealthy Pomeranian family and a father who pursued entomology and with whom he long maintained a difficult relationship. During his undergraduate years he was strongly influenced by two books, Darwin's *Origin of Species* and Lang's *History of Materialism,* the latter of which made him differ from leading biologists such as Haeckel and Vogt. The details of these issues during this period of intellectual ferment merit greater study. Dohrn's early work on insects and crayfish underpinned his continuing interest in arthropod and vertebrate phylogeny. A project which he conceived in 1869, the Aquarium and Station were originally designed without kitchen or female guests so that they could not serve as a hotel or bordello. Dohrn provided both the scientific vision, encapsulated in a classic essay, and administrative adroitness, particularly the system of rented work tables, amid both local and international political upheavals. The institution prospered to include botany, boats, publications, and technical research. In his final years Dohrn received international acclaim, his family thrived, and his Station expanded with support from numerous sources. The volume is lightly illustrated and includes key letters by Dohrn and updates on the histories of the family and Station since the original writing. Dohrn's strategy is neatly summarized in a single sentence from one of these letters dated 1884: "What Darwin produced through his individual books, each of which created almost a new discipline, I succeeded in doing by creating new organizational turns."

The book is valuable as an exposition of scientific fund raising in the second half of the nineteenth century and of the antagonism, still with us, of international science versus national politics. Heuss was a distinguished politician and biographer, but given his non-scientific background it is not surprising that the discussion of the scientific issues of Dohrn's time, or the variegated contributions of his Station, receive attention which many readers will find insufficient. The inclusion of the scientific evaluation of Dohrn by Alfred Kühn is therefore especially informative. Notwithstanding this shortcoming, the appearance of this biography in English is welcome. May it be followed by those of other major figures such as Oskar Heinroth.

PATRICK W. COLGAN

Canadian Museum of Nature, P.O. 3443, Station D, Ottawa, Ontario K1P 6P4

The River of the Mother of God and Other Essays by Aldo Leopold

Edited by Susan L. Flader and J. Baird Callicott. 1991. University of Wisconsin Press, Madison. 384 pp. U.S. $24.95.

The mid-twentieth century witnessed the emergence of the modern field of ecology, and this development is nowhere more evident than in the writings of Aldo Leopold. Known largely today for his conservation classic, *A Sand County Almanac* (1949), published the year after his death, Leopold was also a devoted essayist and commentator on the subjects of wilderness, conservation, and environmental ethics. Some sixty of these articles — several of them unpublished or other inaccessible — have been assembled in a new collection, entitled *The River of the Mother of God.* Each essay is accompanied by a brief introduction which explains the significance of the particular item and provides important context. The collection is also nicely rounded out with a short chronology of Leopold's life and a detailed listing of his published work.

The value of the work, however, is in the essays themselves. Editors Flader and Callicott selected the entries with an eye to illustrating the evolution of Leopold's thinking over a four-decade period, 1904 to 1947. And the result is truly revealing. The Leopold who passionately extolled the need for an ecological conscience in 1947 had earlier argued as a member of the U.S. Forest Service that the spread of civilization would actually *improve* nature! And the same man who had been one of the solitary voices for the protection of hunted species, especially carnivores, had at one time believed that there were good and bad animals and that varmints should be eradicated. Clearly, the prophet Leopold was not born on the mountain but had to find his own way to the summit — just as ecology itself developed and matured over the same period.

W. A. WAISER

University of Saskatchewan, Saskatoon, Saskatchewan R3C 4B7

White Bears and Other Curiosities: The First One Hundred Years of the Royal British Columbia Museum

By Peter Corley-Smith. 1989. Crown Publications, Royal British Columbia Museum, Victoria. 148 pp., illus.

Taking his cue from the axiom that people make an institution, Peter Corley-Smith has written a history of the Royal British Columbia Museum which is more of about the individuals who worked there than it is about the museum itself. After briefly outlining the circumstances behind the establishment of the provincial museum in 1886, the author proceeds to tell the story of the institution through the terms of its various directors and scientific staff and how each left their own particular imprint. Corley-Smith also takes time from the main narrative to describe the development of the museum's facilities and programmes, as well as its more notable collecting activities, such as the search for the elusive Dawson Caribou (*Rangifer dawsoni*) on the Queen Charlotte Islands. The text itself is richly illustrated by a number of fascinating photographs — albeit at times too small — and sketches of personalities associated with the museum.

White Bears and Other Curiosities is intended as a popular account of the provincial museum, and the book's style is easy and engaging — although there is a tendency at times to jump from topic to topic. The author also places greater emphasis on the natural history side of the museum's work at the expense of ethnological activities. Finally, the title is deceptive; although the book is supposed to examine the museum's first century, it deals only with the period from 1886 to 1968.

W. A. WAISER

Department of History, University of Saskatchewan, Saskatoon, Saskatchewan S7N 0W0

The U.S. Outdoor Atlas & Recreation Guide

By John Oliver Jones. 1992. Houghton Mifflin Company, New York. 191 pp., illus. + maps. U.S. $16.95.

Outdoor recreation is a very big business in the United States. It is difficult to comprehend the immense size of this industry, until confronted with the scale as portrayed in this book.

John Jones has assembled an almost comprehensive inventory of wildlife and outdoor recreation areas in the United States. The goal of the book is to present, in one volume, a listing of all sites along with the critical information that a potential user needs. Maps are included of each state, with coded site information. The book lists all federal agency sites, a selection of state parks and wildlife areas, and a very useful compendium of private reserves. Each site has information on 44 categories, such as: the presence of a visitor centre, handicapped services, wildlife checklists, campsites, permitted activities, and food services. A total of 3987 locations are documented across the United States. All states, including Alaska and Hawaii, are included. Puerto Rico and the U.S. Virgin Islands are not.

A very useful section outlines the availability of maps from the Bureau of Land Management (BLM), the U.S. Forestry Service (USFS), and the U.S. Geological Service (USGS). Some state map services are also documented.

I am unable to verify the accuracy of the data. The listing of telephone numbers for hundreds of local offices is a gold mine, but one that is sure to become out of date quickly. Given constantly changing circumstances, the book will have to be updated frequently. I decided to check the map for the State of Washington against the 1983 edition of the Canadian Automobile Association-Reader's Digest excellent book of road maps, Drive North America. A few questions arose. Why is Kaniksu National Forest not included? Why is the large Mt. Spokane State Park left out? Why is the office for Hell's Canyon National Recreation Area listed as Clarkston, Washington, when the recreation area is found in Oregon?

The author states that there are far too many state parks and wildlife areas to be included in a single book. I question if this is a real limitation. The author has chosen, quite arbitrarily, to include some areas and leave out others. The omissions are sometimes striking. Presque Isle State Park, in Lake Erie off Erie, Pennsylvania, hosts several million visitors a year in a well-managed, sand spit locale. It was missed in the book. How many other significant state facilities are not included?

The maps are schematic in form. If one wants to actually find these sites, a more detailed road map is needed. The map symbols used to represent sites are little triangles and circles. They give no indication of the size of the site, and only a general indication of its location. A million-acre national forest gets the same size symbol as a 100-acre Audubon nature reserve.

An information source like this would be even more useful if placed into the context of a computerized Geographical Information System and a data base manager. Imagine having the ability to ask

interactive questions. What recreation sites have good wildlife viewing within 100 miles of Spokane? Where is the closest Forest Service campground to Highway 309? What National Parks occur in Montana? Given the constantly expanding software availability in this field, one might expect such a resource within the decade.

This book fills a vital need. No other publication of this type exists. As a result, it is a valuable resource document. Any outdoor recreationist planning a trip to the U.S. can benefit from having a copy. When is something going to be done for Canada?

PAUL F. J. EAGLES

Department of Recreation and Leisure Studies, University of Waterloo, Waterloo, Ontario N2L 3G1

Evolutionary Innovations

Edited by Matthew H. Nitecki. 1991. University of Chicago Press, Chicago. x + 304 pp., illus. Cloth U.S. $44.95; paper U.S. $17.95.

Throughout the history of life, organisms of all kinds have attempted new ways of surviving and thriving in their environments. Success is determined in a rather unceremonious way by nature, which simply awards life or death to the various inventions — and their inventors. When a good adaptation is justly rewarded and allows its bearer an edge in competitive circumstances, the organisms' subsequent proliferation may define a new branch in its family tree. The point of divergence in these scenarios, or more specifically the generation and spread of these original adaptations, is explored from several different viewpoints in *Evolutionary Innovations*.

Although widely diverse in design and significance, phylogenetic novelties are the single topic of discussion in this collection of essays. In his introduction, editor Matthew Nitecki admits that he is not presenting a synthesis of the work done in this area (as one is not yet possible) but a cross-section of historical and modern ideas. The reader is given a succinct account of the development of thought concerning evolutionary innovations; from Darwin's recognition of natural selection, to the tremendous impact of Ernst Mayr's work in recent times. Nitecki devotes the remainder of his introduction to a presentation of the theoretical and conceptual outlooks of the research being done today.

The ten contributions to this volume are grouped into four large categories. Each group represents a particular aspect of evolutionary novelty, its nature and origin, consequences, and the historical framework in which we study it.

Authors address a range of subjects from the genetic and developmental mechanisms to the ecological consequences of evolutionary change. Theories are illustrated with both modern and fossil data, using a variety of organisms from sand-dollars to solenoglyph snakes. Despite this assortment, the appearance and spread of novel adaptations remains the central concept.

The papers presented in *Evolutionary Innovations* were certainly not culled from other literature. Each author has gone to great lengths in considering his essay's place in the compilation and addressed this question. Many of the pieces are beautifully illustrated, and all are fully referenced with plenty of suggestions for further reading. The editor supplies an excellent index, surprisingly thorough for such a mixture of material.

While everyone may not feel compelled to have this book in their possession it is certainly something to look for in the library. Well written and complete in its coverage of rather specialized subject matter, *Evolutionary Innovations* is worth looking into.

LESLIE R. GOERTZEN

Department of Botany, University of British Columbia, Vancouver, British Columbia V6T 2B1

NEW TITLES

Zoology

*__The great bear: contemporary writings on the grizzly.__ 1992. Edited by John A. Murray. Alaska Northwest Publications, GTE Discovery, Bothell, Washington. 248 pp. U.S. $14.95.

†__A guide to feeding winter birds in Ontario.__ 1991. By Bob Waldon. Whitecap Books, Vancouver, Toronto. xiii + 222 pp., illus. $15.95.

†__Landscape with reptile: rattlesnakes in an urban world.__ 1992. By Thomas Palmer. 340 pp. U.S. $19.95.

__Life histories of North American Woodpeckers.__ 1992. By Arthur Cleveland Bent. Indiana University Press, Bloomington. 296 pp., illus.

*__The modern beginnings of subarctic ornithology: correspondence to the Smithsonian Institute, 1856 – 1868.__ 1991. Edited by Debra Lindsay. Manitoba Record Society Publications, Winnipeg.

*__My way to ornithology.__ 1992. By Olin Sewall Pettingill, Jr. Oklahoma University Press, Norman. xiv + 245 pp., illus. U.S. $24.95.

__Nemerid fishes of the world.__ 1991. FAO Species Catalogue. Unipub, Lanham, Maryland. 149 pp., illus. U.S.$45.

*__Oklahoma bird life.__ 1992. By Frederick M. and A. Marguerite Baumgartner. University of Oklahoma Press, Norman. 548 pp., illus. U.S. $49.95.

__Playback and studies of animal communication.__ 1992. Edited by Peter K. McGregor. Proceedings of a conference 5 – 9 August, 1991, Chesterfield, England. Plenum, New York. c224 pp. U.S. $75.

*__Reptiles and amphibians.__ 1992. By Roger Conant, Robert C. Stebbins, and Joseph T. Collins. Peterson First Guides. Houghton and Mifflin, New York. 128 pp., illus. U.S. $4.95.

__Walker's mammals of the world.__ 1992. By Ronald M. Nowak. 5th edition. Johns Hopkins University Press, Baltimore. 1732 pp. in 2 volumes, illus. U.S. $89.95.

*__Antarctic birds: ecological and behavioral approaches.__ 1992. By David Freeland Parmelee. University of Minnesota Press, Minneapolis. xviii + 203 pp., illus. U.S. $39.95.

†__Care of the wild: first aid for all wild creatures.__ 1992. By William J. Jordan and John Hughes. University of Wisconsin Press, Madison. xii + 225 pp., illus. Cloth U.S.$27.50; paper U.S. $11.95.

__Climate variability, climate change, and fisheries.__ 1992. Edited by Michael H. Glantz. Cambridge University Press, New York. c360 pp., illus. cU.S. $59.95.

*__The conservation of insects and their habitat.__ 1991. Edited by N.M. Collins and J.A. Thomas. Symposium of the Royal Entomological Society, 14 – 15 September 1989. Academic Press (Harcourt Brace Jovanovich, London). xviii + 450 pp., illus. U.S. $79.

__Current ornithology__, Volume 9. 1992. Edited by Dennis M. Power. Plenum, New York. c238 pp. U.S. $69.50.

Botany

†__Atlas of Ontario mosses.__ 1992. By Robert R. Ireland and Linda M. Ley. Syllogeus 70. Canadian Museum of Nature, Ottawa. 138 pp., illus.

__Bignoniaceae - Part II (tribe Tecomeae).__ 1992. By Alwyn H. Gentry. New York Botanical Garden, Bronx. Illus. U.S. $74.75 in U.S.A.; U.S. $76.65 elsewhere.

*__Catalogue of the Colorado flora.__ 1992. By Ronald C. Whittmann and William A. Weber. University Press of Colorado, Niwot. 272 pp. U.S. $34.95.

†__Common and botanical names of weeds in Canada/Noms populaires et scientifiques des plantes nuisibles du Canada.__ 1991. By Gerald A. Mulligan. Revised edition Agriculture Canada, Ottawa. 131 pp. $12 in Canada; U.S. $12 in U.S.A.; U.S. $14.40 elsewhere.

__Fire and vegetation dynamics: studies from the North American boreal forest.__ 1992. By Edward A. Johnson. Cambridge University Press, New York. c175 pp., illus. cU.S. $59.95.

__Growth and reproductive strategies of freshwater phytoplankton.__ 1992. Edited by Craig D. Sandgren. Cambridge University Press, New York. 448 pp., illus. U.S. $24.95.

†__The lichens of southern Ontario, Canada.__ 1992. By Pak Yau Wong and Irwin M. Brodo. Syllogeus 69. Canadian Museum of Nature, Ottawa. 79 pp., illus.

__Life strategies of succulents in deserts: with special reference to the Namib Desert.__ 1992. By Dieter J. von Willert, Benno M. Eller, Marinus J.A. Werger, Enno Brinckmann, and Hans-Dieter Inlenfeldt. Cambridge University Press, New York. c333 pp., illus. cU.S. $69.95.

__The Limnocharitaceae.__ 1992. By Robert R. Haynes and Lauritz B. Holm-Nielsen. New York Botanical Garden, Bronx. 34 pp. U.S. $16.25 in U.S.A.; U.S. $17.50 elsewhere.

__New flora of the British Isles.__ 1992. By Clive A. Stace. Cambridge University Press, New York. c1250 pp., illus. cU.S.$59.95.

†__North American range plants.__ 1992. By James Stubbendieck, Stephan L. Hatch, and Charles H. Butterfield. 4th edition. University of Nebraska Press, Lincoln. xv + 493 pp., illus. Cloth U.S. $45; paper U.S. $20.

__Seeds of woody plants.__ 1992. by James A. and Cheryl G. Young. Timber Press, Portland, Oregon. c525 pp., illus. U.S. $49.95.

__*Sensitivae cen sitae:* a description of the genus *Mimosa* Linnaeus (Mimosaceae) in the new world.__ 1991. By Rupert C. Barneby. New York Botanical Garden, Bronx.

835 pp., illus. U.S. $138.40 in U.S.A.; U.S. $142.10 elsewhere.

Spore atlas of New Zealand ferns and fern allies. 1991. By Mark Large and John Braggins. SIR Publishing, Wellington, New Zealand. ix + 168 pp., illus. U.S. $50.

Studies on *Amanita* (Amanitaceae) from Andean Colombia. 1992. By Rodham E. Tulloss, Clark L. Ovrebo, and Roy E. Halling. New York Botanical Garden, Bronx. 46 pp., illus. U.S. $18.60 in U.S.A.; U.S. $19.90 elsewhere.

Environment

*__The balance of nature: ecological issues in the conservation of species and communities.__ 1992. By Stuart L. Pimm. University of Chicago Press, Chicago. 464 pp., illus. Cloth U.S. $62; paper U.S. $26.95.

Ecological risk estimation. 1992. By Steven M. Bartell, Robert H. Gardner, and Robert V. O'Neill. CRC Press, Boca Raton, Florida. c425 pp. cU.S. $69.95 in U.S.A.; cU.S. $84 elsewhere.

The ecology of recently - deglaciated terrain: a geoecological approach to glacier forelands. 1992. By John A. Matthews. Cambridge University Press, New York. c400 pp., illus. cU.S. $110.

†**Kimberley rainforests of Australia.** 1991. Edited by N.L. McKenzie, R.B. Johnston, and P.G. Kendrick. Surrey Beatty, Chipping Norton, Australia. xiv + 490 pp., illus. + plates. A $93 plus postage.

*__The miner's canary.__ 1991. By Niles Eldredge. Prentice Hall Press, Toronto. 246 pp., illus. $20.

†**Monitoring ecological change.** 1992. By Ian F. Spellerberg. Cambridge University Press, New York. xvi + 334 pp., illus. U.S. $79.95.

The nature of southeast Alaska: a guide to the plants, animals, and habitats. 1992. By R. Armstrong, R. Carstensen, and R. O'Clair. Alaska Northwest Books, GTE Discovery Publications, Bothell, Washington. 256 pp., illus. U.S. $17.95.

Risk management of chemicals. 1992. Edited by Mervyn Richardson. CRC Press, Boca Raton, Florida. c450 pp. cU.S. $150.

†**Seashores.** 1992. By John C. Kricher. Peterson First Guides. Houghton Mifflin, New York. 128 pp., illus. U.S. $4.95.

*__The U.S. outdoor atlas and recreation guide.__ 1992. By John Oliver Jones. Houghton Mifflin, Boston. 191 pp., illus. U.S. $16.95.

*__Water quality in North American river systems.__ 1992. Edited by C.D. Becker and D.A. Neitzel. Battelle Press, Columbus, Ohio. 328 pp. U.S. $44.95 + U.S. $3.50 postage.

Miscellaneous

*__Anton Dohrn: a life for science.__ 1991. By Theodor Heuss. Springer-Verlag, New York. xxxvi + 401 pp., illus. U.S. $50.

†__Canyon: the ultimate book on whitewater rafting in Grand Canyon.__ 1992. By Michael P. Ghiglierti. University of Arizona Press, Tuscon. xvi + 311 pp. Cloth U.S. $29.95; paper U.S. $15.95.

Classification, evolution, and the nature of biology. 1992. By Alec L. Panchen. Cambridge University Press, New York. c350 pp., illus. Cloth cU.S. $54.95; paper cU.S. $19.95.

Directory of arctic science and technology research in Canada. 1991. Circumpolar Scientific Affairs Directorate. Indian and Northern Affairs Canada, Ottawa. 297 pp.

*__Extinction, bad genes or bad luck?__ 1991. By David M. Raup. Norton, New York. 210 pp., illus.

†__Minutes of meetings, 1920 – 1923, McIlwraith Ornithological Club, London, Ontario.__ 1992. By W.W. Judd. Phelps Publishing, London. 81 pp. $10.

*__Queen's biology: an academic history of innocence lost and fame gained, 1858 - 1965.__ 1991. By B.N. Smallman, H.M. Good, and A.S. West. Department of Biology, Queen's University, Kingston. xiv + 215 pp., illus.

*__Three men of the Beagle.__ 1991. By Richard Lee Marks. Knopf, New York. 256 pp., illus. U.S. $29.

* assigned for review
† available for review

Index to Volume 106

Compiled by Leslie Cody

Abalone, Northern, 3
Abies balsamea, 112, 192, 366, 436
Acacia farnesiana, 324
Acanthocyclops vernalis, 464
Acantholumpenus mackayi, 2
Acarospora veronensis, 105
Accipiter cooperii, 474
    striatus, 500
Accipiter cooperii, in northern New Jersey and southeastern New York, Nest sites and habitat selected by Cooper's Hawks, 474
Acer glabrum, 328
    rubrum, 118, 367, 443, 475
    saccharum, 112, 366, 443, 475
Achillea lanulosa, 219
    millefolium, 219, 334, 456
    nigrescens, 98
Acipenser brevirostrum, 2
    fulvescens, 2
    medirostris, 2
    oxyrhynchus, 4
    transmontanus, 2
Acrocheilus alutaceus, 4
Acroperus harpae, 464
Actitis macularia, 495
Adelolechia pilati, 106
Aechmophorus occidentalis, 485
Agelaius phoeniceus, 211, 319
Agropyron spp., 185
    pectiniforme, 220
    repens, 220
    sibiricum, 219
    spicatum, 327
    trachycaulum, 456
    violaceum ssp. *violaceum*, 343
    violaceum var. *hyperarcticum*, 91
Agyrophora lyngei, 106
Ainley, M. G., review by, 548
Alaska, Recent Sightings of Harbour Porpoises, *Phocoena phocoena*, near Point Barrow, 489
Alaska, The Status of Selected Birds in East-central, 316
Alaskan Islands, Red Foxes, *Vulpes vulpes*, as Biological Control Agents for Introduced Arctic Foxes, *Alopex lagopus*, on, 200
Alca torda, 429
Alces alces, 435
Alces alces, in Northern New Hampshire, Use of Roadside Salt Licks by Moose, 112
Alectoria nigricans, 106
    ochroleuca, 106
Alkali-grass, Deschampsia-like, 344
    Small Weeping, 344
Alle alle, 226
Allolumpenus hypochromus, 2, 19
Allolumpenus hypochromus, in Canada, Status of the, Y-Prickleback, 19
Alloteuthis sp., 60
Alopecurus alpinus, 343
Alopex lagopus, 200, 225
Alopex lagopus, on Alaskan Islands, Red Foxes, *Vulpes vulpes*, as Biological Control Agents for Introduced Arctic Foxes, 200
Alopex lagopus, in Svalbard, Food Habits and Observations of the Hunting Behaviour of Arctic Foxes, 225
Alosa aestivalis, 2
Alumroot, Roundleaf, 333
Amara quenseli, 311
Amaranthus retroflexus, 222
Ambloplites rupestris, 12
Amblystegiaceae, 102
Ambrose, R. E., 316
Ambrosia psilostachya, 456
Ambystoma jeffersonianum, 197
    lateral, 196
    maculatum, 197
    opacum, 196
    texanum, 196
    texanum tigrinum, 196
    tigrinum, 196, 312
Ambystoma opacum, on Kelleys Island, Lake Erie, Electrophoretic Identification of the Marbled Salamander, 196
Amelanchier sp., 80
    alnifolia, 185, 328
    alnifolia var. *alnifolia*, 80
    alnifolia var. *compacta*, 80
    sanguinea, 80
Ammocrypta pellucida, 4
Ammodramus bairdii, 211
Ammodytes spp., 433
    americanus, 68
    dubius, 68
Ammophila breviligulata, 354
Amphibolus weglarskae, 304
Anaptychia setifera, 106
Anarichus orientalis, 2
Anas acuta, 471
    clypeata, 183
    fulvigula, 436
    platyrhynchos, 316, 483
    strepera, 214
Anastrophyllum minutum, 101
Anchovy, 60
Andromeda glaucophylla, 536
    polifolia, 96, 346, 375
Andropogon furcatus, 82
    gerardii, 80
Androsace chamaejasme var. *arctica*, 97
Androsace septentrionalis, 97, 346
Anemone cylindrica, 80
    parviflora, 94
    richardsonii, 94
    virginiana, 80
Aneura pinguis, 101
Aneuraceae, 101
Anguilla rostrata, 12
Annectina viriosa, 467
Anser brachyrhynchus, 226
Antennaria angustata, 98
    canescens, 346

compacta, 98
ekmaniana, 98
friesiana, 98
Aphyllon uniflorum, 80
Aplodon wormskjoldii, 101
Aquila chrysaetos, 507
Arabis arenicola, 345
holboellii, 332
Archambault, S. and Y. Bergeron. Discovery of a Living 900 Year-old Northern White Cedar, *Thuja occidentalis*, in Northwestern Québec, 192
Arctagrostis latifolia ssp. *arundinacea*, 91
latifolia ssp. *latifolia*, 91, 343
Arctic Collection of the Fowler Herbarium, Queen's University, 1828-1977, The, 272
Arctoparmelia separata, 106
Arctophila fulva, 91, 343
Arctosa sp., 466
Arctostaphylos alpina, 346
rubra, 96
uva-ursi, 185
Ardea herodias, 483
Arenaria humifusa, 93, 345
Arenaria interpres, 318
Armeria maritima ssp. *labradorica*, 97, 346
Arnica alpina ssp. *angustifolia*, 98
angustifolia ssp. *angustifolia*, 98
griscomii ssp. *frigida*, 98
louiseana ssp. *frigida*, 98
sororia, 334
Arnica, Alpine, 98
Twin, 334
Arnold, T. W. and P. A. Martin. Winter Habitat Use by Male and Female American Kestrels, *Falco sparverius*, in Southwestern Ontario, 336
Aronia melanocarpa, 375
prunifolia, 536
Arrow-grass, 91, 508
Artemesia sp., 319, 456
absinthium, 222
biennis, 221
borealis, 98
frigida, 328
hyperborea, 98
tilesii, 98
tridentata, 327
Artocparmelia separata, 107
Asclepias tuberosa
Asemichthys taylori, 5
Ash, 367
White, 366
Asio capensis, 354
flammeus, 352
Asio flammeus, Nest Sites, Reproduction, and Territory Sizes in Coastal Massachusetts, Notes on Short-eared Owl, 352
Aspen, 112, 181, 324, 366, 443
Quaking, 319
Trembling, 185, 436
Aspen Succession on Sharp-tailed Grouse, Grouse, *Tympanuchus phasianellus*, in the Interlake Region of Manitoba, Effects of, 185
Asphodel, False, 93
Northern False, 344
Small False, 344
Aspicilia alboradiata, 106
caesiocinerea, 106
candida, 106
disserpens, 106
elevata, 106
lesleyana, 106
myrinii, 106
perradiata, 106
plicigera, 106
ryrkaipiae, 106
supertegens, 106
Aster spp., 185
azureus, 80
ericoides, 80
ericoides pansus, 456
multiflorus, 80
nemoralis, 375, 536
oolentangiensis, 80
pauciflorus, 456
pygmaeus, 98
sibiricus, 98
undulatus, 80
Aster, 185
Astragalus alpinus, 96, 345
eucosmus, 96, 345
purshii, 333
Atkinson, J. E., reviews by 161, 288, 291, 411, 412, 421, 454
Atriplex patula, 456
Auk, Little, 226
Aulacomnium acuminatum, 102
palustre, 102
turgidum, 102
Avena fatua, 219
sativa, 220
Avens, Mountain, 95
Avocet, American, 471, 507
Avocet, *Recurvirostra americana*, Breeding Records in the Northwest Territories, with Notes on Avocet Parasitism of Mew Gull, *Larus canus*, Nests, Recent American, 507
Axyris amaranthoides, 222
Aythya affinis, 378
americana, 378
collaris, 378
fuligula, 380
marila, 378
valisineria, 378, 471
Azalea, Alpine, 346

Bacidia bagliettoana, 107
siberiensis, 107
sphaeroides, 107
Bahret, S., 216
Bailey, E. P. Red Foxes, *Vulpes vulpes*, as Biological Control Agents for Introduced Arctic Foxes, *Alopex lagopus*, on Alaskan Islands, 200
Baird, R. W., reviews by 288, 413
Balaena mysticetus, 3
Balaenoptera acutorostrata, 5
borealis, 5
musculus, 3
physalus, 3, 70
Balsamorhiza sagittata, 328
Balsamroot, Arrowleaf, 328

Banasch, U., J. P. Goossen, A. E. Riez, C. Casler, and R. D. Barradas. Organochlorine Contaminants in Migrant and Resident Prey of Peregrine Falcons, *Falco peregrinus*, in Panama, Venezuela, and Mexico, 493
Barradas, R. D., 493
Bartonia paniculata ssp. *iodandra*, 375
Bartramia longicauda, 318
Bass, Largemouth, 17
Rock, 12
Smallmouth, 11, 17
Striped, 4
Baydack, R. K., 185
Bear, Polar, 226
Bearberry, 185
Alpine, 346
Beaudoin, A. B., reviews by, 282, 293
Bedstraw, Common, 185
Beech, 112
American, 475
Beetle, Ground, 311
Belant, J. L., reviews by, 159, 160, 282, 544
Bell, Yellow, 333
Beluga, 3
Benson, J. M., reviews by, 169, 170, 283, 408, 413, 414, 543, 546
Berardius bairdii, 5
Berger, R. P. and R. K. Baydack. Effects of Aspen Succession on Sharp-tailed Grouse, *Tympanuchus phasianellus*, in the Interlake Region of Manitoba, 185
Bergeron, Y., 192
Berry, Sheep, 80
Betula alleghaniensis, 112, 366
glandulosa, 93, 185, 334, 350
lenta, 475
minor, 348
occidentalis, 348
papyrifera, 112, 192, 366, 436, 443
Betula occidentalis, Outlier of the Northwestern Hudson Bay Lowlands, Re-examination of a Water Birch, 348
Beyens, L., 303
Bilberry, 97
Bog, 346
Birch, Black, 475
Dwarf, 93, 185
Glandular Dwarf, 344
Ground, 93
Paper, 192, 443
Water, 348
White, 112, 366, 436
Yellow, 112, 366
Birch, *Betula occidentalis*, Outlier of the Northwestern Hudson Bay Lowlands, Re-examination of a Water, 348
Birds in East-central Alaska, The Status of Selected, 316
Birt, T. P., 175
Bison, 324
Bison bison, 324
Bistort, 93
Alpine, 344
Blackbird, Brewer's, 211
Red-winged, 211, 319
Rusty, 380
Yellow-headed, 211
Bladder-Campion, 94
Bladderpod, Arctic, 95
Blepharostoma trichopyllum, 101
Bloater, 2
Bluebell, Alpine, 346
Blueberry, 118
Swamp, 80
Bluebird, Mountain, 319
Bluegill, 246
Bluegrass, Arctic, 91
Glaucous, 91
Kentucky, 328
Sandberg's, 328
Bluejoint, 91
Boatman, Water, 466
Boe, J. S. Wetland Selection by Eared Grebes, *Podiceps nigricollis*, in Minnesota, 480
Bodolink, 495
Bog-Orchid, Northern, 93
Bog-Rosemary, 346
Bog-Rush, 92
Bogart, J. P. 196
Bombycilla cedrorum, 211
Bombycilla garrulus, 500
Bosakowski, T., D. G. Smith, and R. Speiser. Nest sites and habitat selected by Cooper's Hawks, *Accipiter cooperii*, in northern New Jersey and southeastern New York, 474
Botrychium obliquum, 80
ternatum var. *obliquum*, 80
Bouteloua curtipendula, 82
Bowerman, W. W., 443
Brachionus angularis, 467
plicatilis, 466
pterodinoides, 466
quadridentatus, 467
Brachythecium turgidum, 103
Brainworm, 116
Branta bernicla, 233
canadensis, 234, 471
canadensis leucopareia, 200
leucopsis
Brassica arvensis, 220
juncea, 222
Braya glabella, 94
humilis, 94
purpurascens, 94, 345
Braya, Low, 345
Breton, L., 435
Bretzke, H., 272
British Columbia: Assessing Optimal Foraging Habitat, Diet of California Bighorn Sheep, *Ovis canadensis californiana*, in, 327
Brodo, F., review by, 170
Brome-grass, 91
Bromus inermis, 219
pumpellianus var. *arcticus*, 91
pumpellianus var. *pumpellianus*, 91
tectorum, 219, 327
Brousseau, P., 427
Brown, D. T., 546
Bryocaulon divergens, 107
Bryoerythrophyllum recurvirostrum, 103
Bryophytes of the Melville Hills Region, Northwest Territories, 100

Bryoria lanestris, 107
nitidula, 107
simplicior, 107
Bryum algovicum, 102
argenteum, 102
calophyllum, 102
cyclophyllum, 102
pseudotriquetrum, 102
weigelii, 102
wrightii, 102
Bubo virginianus, 311
Bucephala albeola, 378
clangula, 378
islandica, 378
Buckwheat, Snow, 328
Wyeth, 328
Buellia notabilis, 107
papillata, 107
punctata, 107
Buffalo, Bigmouth, 2
Black, 2
Smallmouth, 17
Buffaloberry, Thorny, 325
Bufflehead, 378
Bulrush, 92
Tufted, 344
Bunting, Snow, 226
Bur-Reed, 90
Burbot, 17
Burns, J. A., review by, 282
Buteo jamaicensis, 211, 316
swainsonii, 211
Buttercup, Boreal, 345
Dwarf, 94
Northern, 345
Northern Seaside, 94, 345
Pallas', 345
Butterfish, 60
Butterfly, Frosted Elfin, 84
Karner Blue, 84
Regal Fritillary, 84
Butterwort, 97

Cactus, 311
Brittle Prickly-pear, 333
Calamagrostis canadensis ssp. *canadensis*, 91
canadensis ssp. *langsdorfii*, 91
deschampsioides, 343
inexpansa, 456
neglecta, 91
pickeringii, 374, 536
purpurascens, 91
stricta, 91
Calanus finmarchicus, 43
Calidris alba, 495
alpina, 380
bairdii, 471
maritima, 226, 380
melanotos, 471
minutilla, 471
pusilla, 471
Calliergon giganteum, 102
richardsonii, 304
sarmentosum, 102
stramineum, 102
trifarium, 102
Calonectis diomedia, 56
Caloplaca ammiospila, 107
borealis, 107
cinnamonea, 107
crenularia, 107
discoidalis, 107
fraudans, 107
holocarpa, 107
jungermanniae, 107
tiroliensis, 107
tominii, 107
Calopogon tuberosus, 374
Caltha palustris var. *arctica*, 94
Calystegia spithamea, 80
Camelina sativa, 219
Campanula uniflora, 98, 346
Campbell, R. E. Status of the Mountain Sucker, *Catostomus platyrhynchus*, in Canada, 27
Campbell, R. E. Status of the Pixie Poacher, *Occella impi*, in Canada, 24
Campbell, R. E. Status of the Y-Prickleback, *Allolumpenus hypochromus*, in Canada, 19
Campbell, R. R. Rare and Endangered Fishes and Marine Mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports VIII, 1
Campion, Apetalous, 345
Arctic, 345
Moss, 94
Campostoma anomalum, 2
Campylium, 100
arcticum, 102
stellatum, 103
Canada up to 1989, Recovery Patterns of Ospreys, *Pandion haliaetus*, banded in, 361
Canadian High-Arctic 1. Freshwater Tardigrades from Devon Island, Northwest Territories, Contributions to the, Tardigrada of the, 303
Candelariella aurella, 107
dispersa, 107
terrigena, 108
Candona acuta, 464
acutula, 463
compressa, 464
distincta, 464
ohioensis, 464
rawsoni, 462
renoensis, 462
Canis latrans, 201
lupus, 201
Canvasback, 378, 471
Capelin, 233, 433
Capsella bursa-pastoris, 220
Caragana spp., 325
arborescens, 219
Caragana, 325
Cardamine bellidifolia, 345
digitata, 94, 345
pratensis, 345
pratensis ssp. *angustifolia*, 94
Carduelis flammea, 500
pinus, 500
tristis, 500
Carex sp., 507
aquatilis, 92, 508

aquatilis var. *aquatilis*, 344
aquatilus var. *stans*, 344
atrofusca, 92, 344
bicolor, 92
bigelowii, 344
capillaris, 92
capillaris ssp. *capillaris*, 344
chordorrhiza, 92
exilis, 374, 536
foenea, 80
glacialis, 92
glareosa var. *amphigena*, 344
lanuginosa, 456
limosa, 508
lugens, 92
maritima, 92, 344
membranacea, 92, 344
microglochin, 92
misandra, 92, 344
nardina, 92
pauciflora, 374
petasata, 333
petricosa, 92
physocarpa, 344
rariflora, 92
rariflora var. *rariflora*, 344
richardsonii, 82
rupestris, 344
saxatilis, 92
saxatilis var. *rhomalea* 344
scirpoidea, 92, 344
siccata, 80
subspathacea, 92, 344
ursina, 92, 344
vaginata, 92, 344
Carp, Common, 17
Carpodacus purpureus, 500
Casler, C., 493
Cassidix mexicanus, 496
Cassiope tetragona, 96
tetragona ssp. *tetragona*, 346
Castilleja caudata, 97
coccinea, 79
elegans, 97
hyperborea, 90
raupii, 346
thompsonii, 329
Castostomus castostomus lacustris, 4
platyrhynchus, 2
Catapyrenium lachneum, 108
Catfish, Flathead, 4
Cathartes aura, 316
Catharus ustulatus, 211
Catling, P. M., V. R. Catling and S. M. McKay-Kuja. The Extent, Floristic Composition and Maintenance of the Rice Lake Plains, Ontario, Based on Historical Records, 73
Catling, V. R., 73
Catoptrophorus semipalmatus, 211, 495
Catoscopium nigritum, 102
Catostomus sp., 3
ardens, 32
catostomus, 30
columbianus, 27
commersoni, 17, 30
discobolus, 32
griseus, 29
platyrhynchus, 27
tahoensis, 32
Catostomus platyrhynchus, in Canada, Status of the Mountain, Sucker, 27
Cattail, 319
Cedar, Northern White, 112, 192, 366
Cedar, *Thuja occidentalis*, in Northwestern Québec, Discovery of a Living 900 Year-old Northern White, 192
Celtis tenuiflora, 82
Centaurea cyanus, 222
diffusa, 332
maculosa, 218
Centropyxis aculeata, 469
constricta, 467
Cephalodella forficula, 467
Cepphus grylle, 226, 429
Cerastium alpinum, 345
beeringianum, 93
regelii, 90
Ceratodon purpureus, 103
Cervus canadensis canadensis, 84
Cetraria cucullata, 108
delisei, 108
ericetorum, 108
fastigiata, 108
islandica, 108
nigricascens, 108
nivalis, 108
tilesii, 108
Chamaedaphne calyculata, 536
Chamomile, Sea-shore, 346
Chandonanthus setiformis, 101
Chapdelaine, G. and P. Brousseau. Distribution, Abundance, and Changes of Seabird Populations of the Gaspé Peninsula, Québec, 1979 to 1989, 427
Char, Red, 4
Chara sp., 31
Charadrius melodus, 471
semipalmatus, 471
vociferus, 211, 380
Cheatgrass, 327
Chelydra serpentina, 241
Chelydra serpentina and *Chrysemys picta*, Ontogenetic changes in habitat use by juvenile turtles, 241
Chenopodium album, 219
berlandieri var. *zsachackei*, 219
rubrum, 483
Cherry, Dwarf, 80
Sand, 80
Chickadee, Black-capped, 211, 500
Chickweed, Alpine, 345
Chiselmouth, 4
Chlidonias niger, 471, 483
Chokecherry, Common, 328
Cholmondeley, R., 206
Chrysanthemum arcticum, 98, 346
integrifolium, 98
leucanthemum, 221
Chrysemys picta, 241
Chrysemys picta, Ontogenetic changes in habitat use by juvenile turtles, *Chelydra serpentina* and, 241
Chrysomyxa arctostaphyli, 316

Chrysosplenium tetrandrum, 95
Chrysothamnus nauseosus, 329
Chub, Creek, 237
Hornyhead, 2
Liard Hotspring Lake, 5
River, 2
Silver, 2
Chubsucker, Lake, 4
Cinclidium, 100
arcticum, 102
latifolium, 102
Cinquefoil, Arctic, 95, 345
Marsh, 96, 345
Shrubby, 95
Snow, 96
Two-flower, 95
Cirsium arvense, 221
Cisco, Arctic, 175
Bering, 2
Blackfin, 2
Deepwater, 3
Least, 490
Longjaw, 3
Shortjaw, 2
Shortnose, 2
Spring, 4
Cisco, *Coregonus autumnalis*, Distribution, Migration and Spawning in the Mackenzie River, Arctic, 175
Cladina mitis, 108, 536
rangiferina, 350
stellaris, 108, 350
terrae-novae, 536
Cladocera, 485
Cladonia spp., 536
amaurocraea, 108
carneola, 108
cervicornis verticillata, 536
coccifera, 108
deformis, 108
gracilis ssp. *gracilis*, 108
phyllophora, 536
pleurota, 108
pocillum, 108
pseudorangiformis, 108
subulata, 108
sulphurina, 108
Cladopodiella fluitans, 536
Clangula hyemalis, 228, 378
Cletocamptus albuquerquensis, 464
Clinostomus elongatus, 2
Closterium, 32
Cloudberry, 345
Club, Gravel, 3
Club-Moss, Mountain, 90, 343
Cluff, H. D. Wolf Scientists Meet in Edmonton, 531
Clupea harengus, 43, 60
Coad, B. W., review by, 164
Coad, N. P., review by, 164
Coccothraustes vespertina, 500
Cochlearia officinalis, 94, 345
Cod, Atlantic, 433
Saffron, 490
Cody, W.J., 216
Cody, W.J., reviews by, 167, 415, 416, 417
Cody, W. J., G. W. Scotter, and S. C. Zoltai. Vascular Plant Flora of the Melville Hills Region, Northwest Territories, 87
Coelocaulon muricatum, 108
Cogdon, J. D., S. W. Gotte, and R. M. McDiarmid. Ontogenetic changes in habitat use by juvenile turtles, *Chelydra serpentina* and *Chrysemys picta*, 241
Colgan, P. W., reviews by, 154, 157, 279, 285, 298, 422, 550
Collema fuscovirens, 108
glebulentum, 108
limosum, 108
tenax, 108
undulatum var. *granulosum*, 108
Cololabis saira, 60
Colpodium vahlianum, 91
Coluber constrictor foxii, 84
Columba livia, 211, 500
Colurella colurus, 467
dicentra, 466
uncinata, 467
Comandra umbellata, 333
Coniosporium lecanorae, 108
Conostomum tetragonum, 102
Cook, F., review by, 545
Coot, American, 318, 380, 483
Cooter, 241
Coral-root, 93
Corallorhiza trifida, 93
Coregonus alpenae, 3
artedi, 4
autumnalis, 175
clupeaformis, 4
clupeaformis spp., 2
hoyi, 2
huntsmani, 3
johannae, 3
kiyi, 2
laurettae, 2
nigripinnis, 2
pidschian, 490
reighardi, 2
sardinella, 179, 490
zenithicus, 2
Coregonus autumnalis, Distribution, Migration and Spawning in the Mackenzie River, Arctic Cisco, 175
Cormorant, Double-crested, 427, 471
Great, 428
Cornus circinata, 80
rugosa, 80
Corvus brachyrhynchos, 181, 211, 500
corax, 500
Corvus brachyrhynchos, in a Waterfowl Breeding Area in Manitoba, Home Range and Foraging Habitat of American Crows, 181
Coryphantha sp., 311
COSEWIC Fish and Marine Mammal Subcommittee Status Reports VIII, Rare and Endangered Fishes and Marine Mammals of Canada:, 1
Cotton-Grass, 92
Beautiful, 344
Close-sheathed, 344
One-spike, 344
Sheathed, 344
Tall, 344
Cottonwood, 316, 483
Cottus aleuticus, 5

bairdi, 5
confusus, 3
ricei, 2
Couesius plumbeus spp., 5
Cowbird, Brown-headed, 211, 500
Coyote, 201
Cranberry, Mountain, 97, 346
Crane, Sandhill, 316
Whooping, 507
Crepis atrabarba, 333
nana, 98
tectorum, 219
Cress, 31
Alpine Bitter, 345
Meadow Bitter, 345
Northern Bitter, 345
Cribroelphidium gunteri, 454
Crins, W. J., review by, 291
Crocodile, 436
Crocodylus porosus, 436
Crossbill, Red, 211
Crossman, E. J., E. Holm, R. Cholmondeley and K. Tuininga. First Record for Canada of the Rudd, *Scardinius erythrophthalmus*, and Notes on the Introduced Round Goby, *Neogobius melanostomus*, 206
Crotalus horridus, 118
Crow, American, 181, 211, 500
Crowberry, 96, 342
Crowder, A., J. Topping, A. E. Garwood, M. Handford, C. Vardy and H. Bretzke. The Arctic Collection of the Fowler Herbarium, Queen's University, 1828-1977, 272
Crows, *Corvus brachyrhynchos*, in a Waterfowl Breeding Area in Manitoba, Home Range and Foraging Habitat of American, 181
Cucurbitella tricuspis, 469
Currant, Squaw, 329
Curry, R. A., 237
Cyanocitta cristata, 500
Cyclocypris ampla, 464
serena, 462
sharpei, 464
Cymindis planipennis, 312
Cyperus filiculmis, 80
lupulinus, 80
Cyphelium inquinas, 108
Cypria ophthalmica, 464
Cypridopsis aculeata, 462
vidua, 462
Cyprinotus carolinensis, 464
glaucus, 464
incongruens, 463
salinus, 462
Cyprinus carpio, 17
Cypripedium pubescens, 80
Cyprois marginata, 464
Cyrtomnium hymenophylloides, 102
hymenophyllum, 102
Cystophora cristata, 3
Cystopteris fragilis, 90, 343
Cytheromorpha fuscata, 454

Dace, Banff Longnose, 3
Blackside, 237
Finescale, 239
Leopard, 2
Nooky, 5
Northern Redbelly, 237
Redside, 2
Southern Redbelly, 237
Speckled, 2
Umatilla, 2
Dace, *Phoxinus eos*, Preliminary Evidence for Fractional Spawning by the Northern Redbelly, 237
Dactylina arctica, 108
madreporiformis, 108
ramulosa, 108
Dactylobiotus dispar, 308
Daisy, Arctic, 98, 346
Dandelion, 98
Incised, 346
Daphnia pulex, 464
Daphnia spp., 485
Darter, Channel, 4
Eastern Sand, 4
Greenside, 2
Least, 2
River, 2
Tessellated, 4, 237
Dawson, G. A., 443
Day, R., review by, 165
Death-Camass, 93
Meadow, 333
Deer, 435
Mule, 436
White-tailed, 116, 357, 435
Deer, *Odocoileus virginianus*, on Anticosti Island, Québec, Application of a Double-count Aerial Survey Technique for White-tailed, 435
Deer, *Odocoileus virginianus*, Released in Upper Michigan, Hunter-harvest of Captive-raised Male White-tailed, 357
Deergrass, 82
Delorme, L. D., 454
Delphinapterus leucas, 3, 39
Delphinium bicolor, 333
Delphinus bairdii, 58
capensis, 58
delphis, 3, 55
Delphinus delphis, in Canada, Status of the Common Dolphin, 55
Dendroica fusca, 366
magnolia, 319
petechia, 211
Dendroica fusca, Breeding Habitat in Upper Michigan, Characteristics of Blackburnian Warbler, 366
Dermatocarpon miniatum, 108
Deschampsia brevifolia, 91
caespitosa, 343
Descurainia sophia, 220
sophioides, 94, 345
Desmatodon leucostoma, 103
De Smet, W. H., 303
Desmodium paniculatum, 80
Devon Island, Northwest Territories, Contributions to the, Canadian High-Arctic 1. Freshwater Tardigrades from, 303
Diacyclops bicuspidatus, 464
thomasi, 464

Diapensia lapponica, 346
Diapensia, Northern, 346
Diaptomus siciloides, 464
Dicranum elongatum, 103
spadiceum, 103
Dicrostonyx spp., 225
Didymodon asperifolius, 103
rigidulus var. *icmadophila*, 103
Difflugia corona, 467
globulus, 469
oblonga, 469
protaeiformis, 469
Dillinger, R. E., Jr., T. P. Birt, and J. M. Green. Arctic Cisco, *Coregonus autumnalis*, Distribution, Migration and Spawning in the Mackenzie River, 175
Dimelaena oreina, 108
Dinsmore, J. J., 181
Diphascon recamieri, 304
Diploschistes muscorum, 108
Diplostomum spathaceum, 32
Distichium capillaceum, 103
Distichlis stricta, 456
Ditrichum flexicaule, 103
Dock, Arctic, 93
Doepker, R. V., 357
Doepker, R. V., R. D. Earle and J. J. Ozoga. Characteristics of Blackburnian Warbler, *Dendroica fusca*, Breeding Habitat in Upper Michigan, 366
Dolphin, Atlantic White-sided, 3, 64
Black-chinned, 65
Bottlenose, 5
Common, 3, 55
Dusky, 65
Hourglass, 55, 65
Pacific White-sided, 3, 65
Peales, 65
Risso's, 3
Saddleback, 55
Spinner, 56
Spotted, 56
Striped, 5
White-beaked, 5, 62, 65
White-bellied, 55
White-sided, 62
Dolphin, *Delphinus delphis*, in Canada, Status of the Common, 55
Dolphin, *Lagenorhynchus acutus*, in Canada, Status of the Atlantic White-sided, 64
Douglas-fir, 329
Dove, Eared, 495
Mourning, 211
Rock, 211, 500
Dowitcher, Long-billed, 494
Short-billed, 494
Draba alpina, 94, 345
cinerea, 95
corymbosa, 95
fladnizensis, 95, 345
glabella, 95, 345
incerta, 90
lactea, 345
nivalis,345
subcapitata, 90
Dreissena polymorpha, 376
Dreissena polymorpha, Concentrations of Migrant Diving Ducks at Point Pelee National Park, Ontario, in Response to Invasion of Zebra Mussels, 376
Drepanocladus aduncus, 103
lycopodioides, 303
lycopodioides var. *brevifolius*, 103
revolvens, 103
uncinatus, 103
Dromaius novaehollandiae, 436
Drosera filiformis, 534
intermedia, 374
rotundifolia, 374
Drosera filiformis in Nova Scotia: An Assessment of Risks of a Proposal to Mine Fuel Peat from its Habitat, The Thread-leaved Sundew, 534
Dryas integrifolia, 95, 100, 345
sylvatica, 95
Dryopteris fragrans, 343
Duck, Diving, 376
Harlequin, 378
Mottled, 436
Old Squaw, 228
Ring-necked, 378
Ruddy, 378, 483
Tree, 495
Tufted, 380
Whistling, 494
Ducks at Point Pelee National Park, Ontario, in Response to Invasion of Zebra Mussels, *Dreissena polymorpha*, Concentrations of Migrant, 376Dunlin, 380
Dupontia fisheri, 91, 343

Eagle, Bald, 316, 354, 436, 443
Golden, 507
Eagles, *Haliaeetus leucocephalis*, to Human Activities in Northcentral Michigan, Responses of Breeding Bald, 443
Eagles, P. F. J., reviews by, 547, 551
Echiniscus spitsbergensis, 304
Echiniscus suillus, 308
Eedy, W., reviews by 162, 419
Eel, American, 12
Eider, 226
Common, 429
King, 378
Eleginus gracilis, 490
Eleocharis sp., 508
Elk, Eastern, 84
Elm, 366
Elymus alaskanus ssp. *hyperarcticus*, 91
arenarius ssp. *mollis*, 91, 343
canadensis, 185
Empetrum nigrum, 375
nigrum ssp. *hermaphroditum*, 346
nigrum var. *hermaphroditum*, 96
Emus, 436
Emydoidea blanghgii, 241
Emydura krefftii, 241
Encalypta alpina, 103
rhaptocarpa, 103
Engraulis encrasicolus, 60
mordax, 60
Enhydra lutris, 3, 436
Ephebe lanata, 108
Epilobium angustifolium, 96
latifolium, 96, 346

leptophyllum, 375
palustre, 346
Equisetum arvense, 90, 343
palustre, 90
scirpoides, 90
variegatum, 90, 343
Earle, R. D., 357, 366
Eremophila alpestris, 211
Erigeron compositus, 98
eriocephalus, 98, 346
filifolius, 332
humilis, 98, 346
Erignathus barbatus, 226
Erimystax x-punctata, 3
Erimyzon sucetta, 4
Eriogonum heracleoides, 328
niveum, 328
Eriophorum angustifolium, 92, 344
brachyantherum, 344
callitrix, 92, 344
scheuchzeri, 92, 344
triste, 92
vaginatum, 92, 344
virginicum, 374, 536
Eris pinea, 466
Erodium cicutarium, 222
Erskine, A. J. A Ten-year Urban Winter Bird Count in Sackville, New Brunswick, 499
Erysimum inconspicuum, 95
pallasii, 95
Eschrichtius robustus, 3
Esox americanus, 12
americanus americanus, 4
americanus vermiculatus, 4
lucius, 12
niger, 4
Etheostoma blennioides, 2
microperca, 2
olmstedi, 4, 237
Eubalaena glacialis, 3
Euchlanis dilatata, 467
incisa, 467
Eumetopias jubatus, 3
Euphagus carolinus, 380
cyanocephalus, 211
Euphorbia corollata, 82
esula, 222
Eurycercus lamellatus, 464
Eutrema edwardsii, 95, 345
Eutrema, Edward's, 345
Everlasting, 98
Evernia divaricata, 108
mesomorpha, 108
perfragilis, 108
Ewins, P. J. and C. S. Houston. Recovery Patterns of Ospreys, *Pandion haliaetus*, banded in Canada up to 1989, 361
Exoglossum maxillingua, 4

Fagus grandifolia, 112, 475
Falco columbarius, 316
femoralis, 496
peregrinus, 316, 342, 493
sparverius, 211, 325, 336
Falco peregrinus, in Panama, Venezuela, and Mexico, Organochlorine Contaminants in Migrant and Resident Prey of Peregrine Falcons, 493
Falco sparverius, in Southwestern Ontario, Winter Habitat Use by Male and Female American, Kestrels, 336
Falcon, Aplomado, 496
Peregrine, 316, 342, 493
Falcons, *Falco peregrinus*, in Panama, Venezuela, and Mexico, Organochlorine Contaminants in Migrant and Resident Prey of Peregrine, 493
Farnoldia jurana, 108
Fayle, D. C. F., 348
Felwort, Marsh, 97
Fern, Curly-Grass, 372
Fragile, 90, 343
Fragrant Shield, 343
Fern, an Addition to the Flora of New Brunswick, *Schizaea pusilla*, Curly-Grass, 372
Fescue, 91
Fescue, Alpine, 343
Rough, 329
Festuca sp., 80
altaica, 91
baffinensis, 91
brachyphylla, 91, 343
richardsonii, 91
rubra, 80
rubra ssp. *richardsonii*, 91
scabrella, 329
tenella, 80
vivipara ssp. *glabra*, 91
Filinia longiseta, 467
terminalis, 467
Finch, Purple, 500
Finlay, J. C., review by, 154
Finucan, S., 237
Fir, Balsam, 112, 192, 366, 436
Fireweed, 96
Fistulariella almquistii, 108
Flax, 96
Fleabane, Arctic, 346
One-flowered, 346
Thread-leaf, 332
Flixweed, Northern, 345
Fluke, Eye, 32
Foraminiferan, 454
Formica, 312
Fox, Arctic, 200, 225
Red, 200, 234
Foxes, *Alopex lagopus*, on Alaskan Islands, Red Foxes, *Vulpes vulpes*, as Biological Control Agents for Introduced Arctic, 200
Foxes, *Alopex lagopus*, in Svalbard, Food Habits and Observations of the Hunting Behaviour of Arctic, 225
Foxes, *Vulpes vulpes*, as Biological Control Agents for Introduced Arctic Foxes, *Alopex lagopus*, on Alaskan Islands, Red, 200
Foxtail, Alpine, 343
Fratercula arctica, 226, 429
Fraxinus spp., 367
americana, 366
Freedman, B., W. Maass and P. Parfenov. The Thread-leaved Sundew, *Drosera filiformis* in Nova Scotia: An Assessment of Risks of a Proposal to Mine Fuel Peat from its Habitat, 534

Fritillaria pudica, 333
Fulgensia bracteata, 108
Fulica americana, 318, 380, 483
Fulmar, 226
Fulmarus glacialis, 226
Fundulus diaphanus, 2
notatus, 2

Gadus morhua, 433
Gadwall, 214
Gaillardia aristata, 332
Galeopsis tetrahit var. *bifida*, 221
Galium boreale, 185
spurium, 222
Gannet, 56
Northern, 427
Gar, Spotted, 2
Garwood, A. E., 272
Gaskin, D. E. Status of the Atlantic White-sided Dolphin, *Lagenorhynchus acutus*, in Canada, 64
Gaskin, D. E. Status of the Common Dolphin, *Delphinus delphis*, in Canada, 55
Gaskin, D. E. Status of the Harbour Porpoise, *Phocoena phocoena*, in Canada, 36
Gasterosteus sp., 2
aculeatus, 122
Gasterosteus, Population, Extended Longevity in a Large-bodied Stickleback, 122
Gastropus stylifer, 467
Gaylussacia sp., 375
baccata, 536
dumosa, 536
Gentian, Five-flowered, 80
Moss, 97
Gentiana alba, 82
detonsa ssp. *detonsa*, 97
propinqua, 97
prostrata, 90
puberulenta, 84
quinqueflora, 80
richardsonii, 97
Gentianella crinita, 80
propinqua ssp. *propinqua*, 97
quinquefolia, 78
Gentianopsis detonsa ssp. *detonsa*, 97
Geopinus incrassatus, 312
George, J. C., 489
Geothlypis trichas, 214
Geum trifolium, 332
Giesy, J. P., 443
Gilbert, B. S., review by, 409
Gingras, A., 435
Ginns, J., reviews by 166, 414, 415, 418
Glaux maritima, 456
Globicephala macrorhynchus, 5
malaena, 5
Goatsbeard, 334
Goby, Round, 206
Tubenose, 209
Goby, *Neogobius melanostomus*, First Record for Canada of the Rudd, *Scardinius erythrophthalmus*, and Notes on the Introduced Round, 206
Godwit, Marbled, 471
Goertzen, L. R., reviews by, 420, 552
Goldeneye, Barrow's, 378
Common, 378
Goldenrod, 312
Northern, 98
Goldfinch, American, 500
Goltz, J. P. and H. R. Hinds. *Schizaea pusilla*, Curly-Grass Fern, an Addition to the Flora of New Brunswick, 372
Goose, Aleutian Canada, 200
Barnacle, 226
Brent, 233
Canada, 234, 471
Pink-Footed, 226
Goosefoot, Coast Blite, 483
Goossen, J. P., 493
Gotte, S.W., 241
Gotwit, Marbled, 211
Grackle, Common, 211, 500
Great-tailed, 496
Grampus griseus, 3
Graptemys nigrinoda, 241
ouachitensis, 241
Grass, Alpine Blue, 344
Alpine Sweet, 344
Arctic Blue, 344
Beach, 354
Blue, 91, 342
Few-flowered Sweet, 344
Flexuous Blue, 344
Goose, 91
Greenland Blue, 344
Holy, 91
Pendent, 343
Polar, 343
Sea Lime, 342
Semaphore, 344
Small Goose, 344
Tufted Hair, 343
Tundra, 343
Violet Wheat, 343
Grass-of-Parnassus, 95
Northern, 345
Small, 345
Gray, P. A., review by, 280
Grebe, Eared, 480
Horned, 484
Pied-billed, 484
Red-necked, 485
Western, 485
Grebes, *Podiceps nigricollis*, in Minnesota, Wetland Selection by Eared, 480
Green, J. M., 175
Gregory, P. T., review by, 163
Grimmia anodon, 103
plagiopodia, 103
Grindelia squarrosa, 456
Grosbeak, Evening, 500
Pine, 500
Groundsel, Northern, 98
Grouse, Sharp-tailed, 185
Grouse, *Tympanuchus phasianellus*, in the Interlake Region of Manitoba, Effects of Aspen Succession on Sharp-tailed, 185
Grubb, T. G., W. W. Bowerman, J. P. Giesy, and G. A. Dawson. Responses of Breeding Bald Eagles,

Haliaeetus leucocephalis, to Human Activities in Northcentral Michigan, 443
Grus americana, 507
canadensis, 316
Guillemot, Black, 226, 429
Brünnich's, 226
Common, 226
Gull, California, 211
Franklin's, 211, 471
Glaucous, 225
Great Black-backed, 429
Herring, 354, 380, 429, 500
Mew, 507
Ring-billed, 211, 380, 428
Gull, *Larus canus*, Nests, Recent American Avocet, *Recurvirostra americana*, Breeding Records in the Northwest Territories, with Notes on Avocet Parasitism of Mew, 507Gum, Black, 475
Gymnostomum aeruginosum, 103
Gypsophila paniculata, 219

Habenaria obtusata, 93
Hair-Grass, 91
Hake, Silver, 68
Haliaeetus leucocephalus, 316, 354, 436, 443
Haliaeetus leucocephalis, to Human Activities in Northcentral Michigan, Responses of Breeding Bald Eagles, 443
Haliotis kamtschatkana, 3
Handford, M., 272
Harebell, Arctic, 98
Harpalus, 313
amputatus, 312
Hawk, Cooper's, 474
Red-tailed, 211, 316
Sharp-shinned, 500
Swainson's, 211
Hawk's-beard, Dwarf, 98
Slender, 333
Hawks, *Accipiter cooperii*, in northern New Jersey and southeastern New York, Nest sites and habitat selected by Cooper's, 474
Heather, Arctic White, 96, 346
Hedysarum alpinum var. *americanum*, 96, 345
mackenzii, 96, 345
Hedysarum, Alpine, 345
Northern, 345
Heleopera sphagni, 469
Helianthemum canadense, 80
Helianthus maximilianii, 456
Helisoma anceps anceps, 467
Hemlock, Eastern, 366, 474
Heron, Great Blue, 483
Herring, 60, 68
Atlantic, 43
Blueback, 2
Lake, 4
Heuchera cylindrica, 333
Hexarthra fennica, 466
Hierochloe alpina, 91, 344
odorata, 456
pauciflora, 91, 344
Hinds, H. R., 372
Hippuris vulgaris, 96, 346
Hirundo pyrrhonota, 496
rustica, 211, 494
Histrionicus histrionicus, 378
Holm, E., 206
Holt, D. W. Notes on Short-eared Owl, *Asio flammeus*, Nest Sites, Reproduction, and Territory Sizes in Coastal Massachusetts, 352
Honckenya peploides var. *diffusa*, 94, 345
Hordeum jubatum, 456
vulgare, 220
Horsetail, Common, 90, 343
Marsh, 90
Variegated, 90, 343
Houston, C. S., 361
Huckleberry, 80
Hudson Bay Lowlands, Re-examination of a Water Birch, *Betula occidentalis*, Outlier of the Northwestern, 348
Huisache, 324
Hybognathus argyritis, 4
nuchalis regius, 4
Hylocomium splendens, 103
Hypericum pyramidatum, 80
Hyperoodon ampullatus, 5
Hypnum bambergeri, 103
procerrimum, 103
revolutum, 103
vaucheri, 103
Hypogymnia austerodes, 108
bitteri, 108
subobscura, 108
vittata, 108
Hypsibius convergens, 306
dujardini, 306

Ichthyomyzon castaneus, 2, 14
fossor, 2, 7
unicuspis, 7
Ichthyomyzon fossor, in Canada, Status of the Northern Brook Lamprey, 7
Ichthyomyzon castaneus, in Canada, Status of the Chestnut Lamprey, 14
Icmadophila ericetorum, 108
Icterus galbula, 211
Ictiobus bubalus, 17
cyprinellus, 2
niger, 2
Ilex glabra, 536
illecebrosus, 60, 68
Ilyocypris bradyi, 462
gibba, 462
Incisalia irus, 84
Indian-wheat, 333
Ionaspis annularis, 108
melanocarpa, 108
Ireland, R. R., review by, 292
Isohypsibius canadensis, 306
granulifer, 306
papillifer bulbosus, 306
schaudinni, 306
tetradactyloides, 306

Jacana, Wattled, 494
Jadammina macrescens, 454
Jaeger, Pomarine, 318
Jay, Blue, 500
John, R., reviews by, 162, 289, 410

Johns, B. W., 507
Jones, I. L., review by, 290
Junco hyemalis, 502
Junco, Dark-eyed, 502
Juncus albescens, 92, 344
arcticus, 93, 344
balticus, 456
balticus var. *alaskanus*, 93
biglumis, 93, 344
bufonius, 219
castaneus, 93, 344
Juneberry, Dwarf, 80
Junegrass, Prairie, 327
Juniper, 435
Ground, 90
Juniperus communis, 90, 536
osteosperma, 435

Kalmia angustifolia, 536
latifolia, 118, 477
Keewatin, Northwest Territories, The Vascular Plant Flora of Rankin Inlet, District of, 342
Kellicottia longispina, 467
Keratella cochlearis, 467
crassa, 467
earlinae, 467
quadrata canadensis, 467
quadrata frenzeli, 467
Kestrel, American, 211, 325, 336
Kestrels, *Falco sparverius*, in Southwestern Ontario, Winter Habitat Use by Male and Female American, 336
Kiliasia athallina, 108
episema, 108
Killdeer, 211, 380
Killifish, Banded, 2
Kingbird, Eastern, 211, 318
Kirkland, G. L. Jr., 118
Kittiwake, 56, 226
Black-legged, 429
Kiyi, 2
Knapweed, Diffuse, 332
Kobresia myosuroides, 92, 100
simpliciuscula, 92
Koeleria cristata, 327
Kogia breviceps, 5
simus, 5
Korol, J. B. The Vascular Plant Flora of Rankin Inlet, District of Keewatin, Northwest Territories, 342
Kuyt, E. and B. W. Johns. Recent American Avocet, *Recurvirostra americana*, Breeding Records in the Northwest Territories, with Notes on Avocet Parasitism of Mew Gull, *Larus canus*, Nests, 507

Labidesthes sicculus, 2
Labrador-tea, Narrow-leaved, 346
Northern, 96
Lactuca hirsuta, 80
Lagenorhynchus acutus, 3, 62, 64
albirostris, 5, 62, 65
australis, 65
cruciger, 65
obliquidens, 3, 65
obscurus, 65
Lagenorhynchus acutus, in Canada, Status of the Atlantic White-sided Dolphin, 64
Lagopus spp., 200
mutus, 203, 225
Lampetra macrostoma, 2
Lamprey, Chestnut, 2, 14
Darktail, 2
Northern Brook, 2, 7
Sea, 11
Vancouver, 2
Lamprey, *Ichthyomyzon castaneus*, in Canada, Status of the Chestnut, 14
Lamprey, *Ichthyomyzon fossor*, in Canada, Status of the Northern Brook, 7
Lance, Northern, 68
Sand, 68
Lanius ludovicianus, 211, 321
Lanius ludovicianus, Population, Habitat Change as a Factor in the Decline of the Western Canadian Loggerhead Shrike, 321
Lanteigne, J. Status of the Chestnut Lamprey, *Ichthyomyzon castaneus*, in Canada, 14
Lanteigne, J. Status of the Northern Brook Lamprey, *Ichthyomyzon fossor*, in Canada, 7
Lappula echinata, 222
Lapwing, Southern, 495
Larix laricina, 112, 366, 374
Lark, Horned, 211
Larkspur, Little, 333
Larus argentatus, 354, 380, 429, 500
californicus, 211
canus, 507
delawarensis, 211, 380, 428
hyperboreus, 225
marinus, 429
pipixcan, 211, 471
Larus canus, Nests, Recent American Avocet, *Recurvirostra americana*, Breeding Records in the Northwest Territories, with Notes on Avocet Parasitism of Mew Gull, 507
Laubitz, D. R., review by, 158
Laurel, Mountain, 118, 477
Leach, J. H., 376
Lebia vittata, 312
Lecane sp., 466
lunaris, 467
Lecania arctica, 108
disceptans, 108
fuscella, 108
Lecanora atrosulphurea, 108
behringii, 108
cenisia, 108
circumborealis, 108
crenulata, 108
epibryon, 108
hagenii, 108
marginata, 108
nordenskioeldii, 108
polytropa, 108
pulicaris, 108
rupicola, 108
saligna, 108
zostera, 108
Lechea intermedia, 80
minor, 80
Lecidea atrobrunnea, 109
botryosa, 109

conferenda, 109
hypnorum, 109
lactea, 109
lapicida, 109
lithophila, 109
lulensis, 109
paupercula, 109
phaeopelidna, 109
plana, 109
ramulosa, 109
subduplex, 109
sublimosa, 109
tessellata, 109
theodori, 109
turgidula, 109
umbonata, 109
Lecidella euphorea, 109
spitzbergensis, 109
stigmatea, 109
Leciographa muscigenae, 109
Ledum decumbens, 96, 346
groenlandicum, 350
Lemming, 225
Lemmus spp., 225
Lepadella ovalis, 467
patella, 467
Lepisosteus ocultus, 2
Lepomis auritus, 2
cyanellus, 2, 17
gulosus, 4
humilus, 2
macrochirus, 246
megalotis, 2
Leptobryum pyriforme, 102
Lespedeza capitata, 80
Lesquerella arctica, 95
Lethenteron alaskense, 2
Leuroglossus stilbius, 60
Leymus mollis ssp. *villosissimus*, 91
Liatris cylindracea, 80
spicata, 82
Lichens of the Cape Parry and Melville Hills Regions, Northwest Territories, 105
Lilium philadelphicum, 80
Lim, B. K., review by, 156
Limnocythere ceriotuberosa, 464
inopinata, 463
itasca, 464
staplini, 462
Limnodromus scolopaceus, 494
Limosa fedoa, 211, 471
Linaria dalmatica, 218
vulgaris, 221
Linum lewisii, 96
sulcatum, 80
virginianum, 80
Liquorice-Root, 96
Lissodelphis borealis, 3
Litvaitis, J. A., 112
Locoweed, Bell's Arctic, 346
Hudson Bay, 346
Maydell, 346
Loiseleuria procumbens, 346
Loligo opalescens, 60
Lolium persicum, 222
Lomatium macrocarpum, 333
Lomatogonium rotatum, 97
Lopadium pezizoideum, 109
Lophodytes cucullatus, 380
Lophozia binsteadii, 101
rutheana, 101
Lota lota, 17
Lousewort, Flame-colored, 346
Labrador, 346
Lapland, 346
Large-flowered, 346
Woolly, 97, 346
Lowcock, L. A and J. P. Bogart. Electrophoretic Identification of the Marbled Salamander, *Ambystoma opacum*, on Kelleys Island, Lake Erie, 196
Loxia curvirostra, 211
Lungwort, Sea, 346
Lupine, 96
Silky, 328
Lupinus arcticus, 96
perennis, 80
sericeus, 328
Luxilus chrysocephalus, 4
Luzula confusa, 93, 344
nivalis, 93
nivalis var. *nivalis*, 344
wahlenbergii, 344
Lycaeides melissa samuelis, 84
Lycopodium selago, 90, 343
Lycopus uniflorus, 456
Lyme-grass, 91
Lymnaea palustris, 467
Lysimachia quadrifolia, 80
Lythrurus umbratilis, 2

Maass, W., 534
Mackerel, 60
Horse, 60
Macrhybopsis storeriana, 2
Macrobiotus sp., 303
dianeae, 306
Madtom, Brindled, 2
Margined, 3
Northern, 4
Magpie, Black-billed, 211, 317
Mallard, 316, 483
Mallotus villosus, 233, 433
Manitoba, Effects of Aspen Succession on Sharp-tailed Grouse, *Tympanuchus phasianellus*, in the Interlake Region of, 185
Manitoba, Home Range and Foraging Habitat of American Crows, *Corvus brachyrhynchos*, in a Waterfowl Breeding Area in, 181
Manitoba, The Origin, Physico-chemistry and Biotics of Sodium Chloride Dominated Saline Waters on the Western Shore of Lake Winnipegosis, 454
Maple, 443
Douglas, 328
Red, 118, 367, 475
Sugar, 112, 366, 475
Marchantia polymorpha, 101
Mare's-Tail, 96, 346
Marsh-marigold, 94
Martin, P. A., 336

Masonhalea richardsonii, 109
Massachusetts, Notes on Short-eared Owl, *Asio flammeus*, Nest Sites, Reproduction, and Territory Sizes in Coastal, 352
Matricaria ambigua, 346
matricarioides, 221
perforata, 221
Matthews, J.V., Jr. 311
McDiarmid, R. M., 241
McKay-Kuja, S. M., 73
McKillop, W. B., R. T. Patterson, L. D. Delorme, and T. Nogrady. The Origin, Physico-chemistry and Biotics of Sodium Chloride Dominated Saline Waters on the Western Shore of Lake Winnipegosis, Manitoba, 454
McNicholl, M. K., review by, 153
Meadowlark, Eastern, 494
Western, 211
Medicago falcata, 219
lupulina, 220
sativa, 219
Meesia triquetra, 102
uliginosa, 102
Megalocypris ingens, 464
Megaptera novaeangliae, 3
Megaspora verrucosa, 109
Melandrium affine, 94, 345
apetalum ssp. *arcticum*, 94, 345
Melanelia incolorata, 109
septentrionalis, 109
stygia, 109
Melanitta fusca, 378
nigra, 378
perspicillata, 378
Melilotus alba, 219
officinalis, 221
Menidia menidia, 237
Merganser, 379
Common, 316
Hooded, 380
Mergus merganser, 316
Mergus, 379
Merlin, 316
Merluccius spp., 60
bilinearis, 68
productus, 60
Mertensia drummondii, 90
maritima, 346
Mesoplodon bidens, 3
carlhubbsi, 3
densirostris, 3
mirus, 3
stejnegeri, 3
Mesquite, Honey, 324
Mexico, Organochlorine Contaminants in Migrant and Resident Prey of Peregrine Falcons, *Falco peregrinus*, in Panama, Venezuela, and, 493
Micarea assimilata, 109
denigrata, 109
melaena, 109
Michigan, Characteristics of Blackburnian Warbler, *Dendroica fusca*, Breeding Habitat in Upper, 366
Michigan, Hunter-harvest of Captive-raised Male White-tailed Deer, *Odocoileus virginianus*, Released in Upper, 357
Michigan, Responses of Breeding Bald Eagles, *Haliaeetus leucocephalis*, to Human Activities in Northcentral, 443
Micromeristius poutassou, 60, 68
Micropterus dolomieui, 11, 17
salmonoides, 17
Microtus sp., 226
pennsylvanicus, 313
Middleton, J., review by, 295
Midge, 485
Miliammina fusca, 467
Milk-Vetch, Alpine, 96, 345
Elegant, 345
Pursh's, 333
Timber, 333
Miller, B. K. and J. A. Litvaitis. Use of Roadside Salt Licks by Moose, *Alces alces*, in Northern New Hampshire, 112
Mills, E. L., review by, 549
Mimus polyglottus, 500
Mink, Sea, 3
Minnesota, Wetland Selection by Eared Grebes, *Podiceps nigricollis*, in. 480
Minnow, Bluntnose, 4
Cutlips, 4
Eastern Silvery, 4
Fathead, 237
Pugnose, 2
Western Silvery, 4
Minuartia biflora, 94
rossii, 94
rubella, 94, 345
stricta, 94
Minytrema melanops, 2
Mirounga angustirostris, 3
Mnium thomsonii, 102
Mockingbird, Northern, 500
Mockorange, 333
Moina rectirostris, 464
Molothrus ater, 211, 500
Monodon monoceros, 3, 39
Monostyla lunaris, 467
Moose, 435
Moose, *Alces alces*, in Northern New Hampshire, Use of Roadside Salt Licks by, 112
Morlan, R. E. and J. V. Matthews, Jr. Range Extension for the Plains Spadefoot, *Scaphiopus bombifrons*, Inferred from Owl Pellets Found near Outlook, Saskatchewan, 311
Morone saxatilis, 4
Moss-Campion, 345
Moth, Sphinx, 312
Mountain-Avens, Entire-leaved White, 345
Mountain-Heather, Purple, 346
Mouse, Deer, 118, 313
Grasshopper, 313
House, 313
White-Footed, 118
Mouse, *Peromyscus leucopus*, Use of Woody Ground Litter as a Substrate for Travel by the White-Footed, 118
Moxostoma carinatum, 2, 17
dusquesnei, 2
erythrurum, 2, 17
hubbsi, 3
macrolepidotum, 17

Muhlenbergia uniflora, 374
Murre, Common, 429
Mus musculus, 313
Muskgrass, 31
Mussel, Zebra, 376
Mussels, *Dreissena polymorpha*, Concentrations of Migrant Diving Ducks at Point Pelee National Park, Ontario, in Response to Invasion of Zebra, 376
Mustard, Northern Tansy, 94
Mustela macrodon, 3
Myadestes townsendi, 316
Myoxocephalus quadricornis, 2
thompsoni, 2
Myrica gale, 374
Myriophyllum exalbescens, 346
Myrmica, 312
Myurella julacea, 102
tenerrima, 102

Narwhal, 3, 39
Nasturtium sp., 31
Needle-and-thread, 327
Needlegrass, 185
Neogobius melanostomus, 206
Neogobius melanostomus, First Record for Canada of the Rudd, *Scardinius erythrophthalmus*, and Notes on the Introduced Round Goby, 206
Neophocoena phocoenoides, 43
Nephroma arcticum, 109
expallidum, 109
Neslia paniculata, 219
New Brunswick, A Ten-year Urban Winter Bird Count in Sackville, 499
New Brunswick, *Schizaea pusilla*, Curly-Grass Fern, an Addition to the Flora of, 372
New Hampshire, Use of Roadside Salt Licks by Moose, *Alces alces*, in Northern, 112
New Jersey and southeastern New York, Nest sites and habitat selected by Cooper's Hawks, *Accipiter cooperii*, in northern, 474
New York, Nest sites and habitat selected by Cooper's Hawks, *Accipiter cooperii*, in northern New Jersey and southeastern, 474
Nocomis biguttatus, 2
micropogon, 2
Nogrady, T., 454
Northwest Territories, Bryophytes of the Melville Hills Region, 100
Northwest Territories, Contributions to the, Canadian High-Arctic 1. Freshwater Tardigrades from, Devon Island, 303
Northwest Territories, Lichens of the Cape Parry and Melville Hills Regions, 105
Northwest Territories, Vascular Plant Flora of the Melville Hills Region, 87
Northwest Territories, with Notes on Avocet Parasitism of Mew Gull, *Larus canus*, Nests, Recent American Avocet, *Recurvirostra americana*, Breeding Records in the, 507
Notemigonus crysoleucas, 206
Notholca acuminata, 467
foliacea, 467
laurentiae, 466
salina, 466
squamula, 466
Notorus miurus, 2
Notropis analostanus, 237
anogenus, 2
buchanani, 4
cornutus, 16
dorsalis, 2
heterodon, 4
photogenis, 2
rubellus, 4
texanus, 4
Noturus insignis, 3
stigmosus, 4
Nova Scotia: An Assessment of Risks of a Proposal to Mine Fuel Peat from its Habitat, The Thread-leaved Sundew, *Drosera filiformis* in, 534
Nuthatch, Red-breasted, 211
White-breasted, 500
Nyssa sylvatica, 475

Oak, 443, 474
Black, 73, 118
Black Scrub, 80
Chestnut, 118, 475
Cray Scrub, 80
Mossy-cup, 80
Red, 475
White, 78, 475
Oatgrass, Downy, 92
Occella impi, 2, 24
verrucosa, 25
Occella impi, in Canada, Status of the Pixie Poacher, 24
Oceanodroma leucorhoa, 427
Ochrolechia frigida, 109
inaequatula, 109
upsaliensis, 109
Odobenus rosmarus rosmarus, 3
Odocoileus spp., 435
hemionus, 436
virginianus, 116, 357, 435
Odocoileus virginianus, on Anticosti Island, Québec, Application of a Double-count Aerial Survey Technique for White-tailed Deer, 435
Odocoileus virginianus, Released in Upper Michigan, Hunter-harvest of Captive-raised Male White-tailed Deer, 357
Oldsquaw, 378
Onchorhynchus tshawytscha, 46
Oncophorus wahlenbergii, 103
Oncorhynchus mykiss, 11, 17, 32
O'Neill, J., review by, 421
Ontario, Based on Historical Records, The Extent, Floristic Composition and Maintenance of the Rice Lake Plains, 73
Ontario, in Response to Invasion of Zebra Mussels, *Dreissena polymorpha*, Concentrations of Migrant Diving Ducks at Point Pelee National Park, 376
Ontario, Winter Habitat Use by Male and Female American Kestrels, *Falco sparverius*, in Southwestern, 336
Onychomys leucogaster, 313
Opsepocodus emiliae, 2
Opuntia fragilis, 333
Orcinus orca, 5
Oriole, Northern, 211
Orobanche uniflora, 80
Orphniospora lapponica, 109

moriopsis, 109
Orthothecium chryseum, 103
strictum, 103
Orthotrichum anomalum, 102
speciosum, 102
Oryzopsis canadensis, 80
Osmerus mordax, 490
spectrum, 4
Osmunda cinnamonea, 374
Osprey, 361, 436
Ospreys, *Pandion haliaetus*, banded in Canada up to 1989, Recovery Patterns of, 361
Ostracode, 454
Otiorhynchus ovatus, 311
Ottawa Field-Naturalists' Club, Additional Proposals for the Revised Constitution of The, 530
Ottawa Field-Naturalists' Club and Contributors to The Canadian Field-Naturalist, Some External Awards to Members of The, 406
Ottawa Field-Naturalists' Club and Request for Additional Proposals, Amendment to the Constitution of The, 269
Ottawa Field-Naturalists' Club, New Honorary Membership and 1991 Awards of The, 527
Ottawa Field-Naturalists' Club, Notice of the 1993 Annual Business Meeting of The, 137
Ottawa Field-Naturalists' Club, Notice of the 1994 Annual Business Meeting of The, 530
Ottawa Field-Naturalists' Club, Revision of the Constitution and By-Laws of The, 146
Ottawa Field Naturalists' Club, 11 February 1992, Minutes of the 113th Annual Business Meeting of The, 139
Ottawa Field-Naturalists' Club 1992 Awards, Call for Nominations: 137
Ottawa Field-Naturalists' Club 1993 Awards, Call for Nominations: The, 530
Ottawa Field-Naturalists' Club 1993 Council, Call for Nominations: 137
Ottawa Field-Naturalists' Club 1994 Council, Call for Nominations: The, 530
Otter, Sea, 3, 436
Ovis canadensis californiana, 327
canadensis canadensis, 331
Ovis canadensis californiana, in British Columbia: Assessing Optimal Foraging Habitat, Diet of California Bighorn Sheep, 327
Owl, Great Horned, 311
Marsh, 354
Short-eared, 352
Owl, *Asio flammeus*, Nest Sites, Reproduction, and Territory Sizes in Coastal Massachusetts, Notes on Short-eared, 352
Owl Pellets Found near Outlook, Saskatchewan, Range Extension for the Plains Spadefoot, *Scaphiopus bombifrons*, Inferred from, 311
Oxyria digyna, 93, 344
Oxytrope, Arctic, 96
Oxytropis arctica, 96
arctobia, 96
bellii, 346
deflexa var. *foliolosa*, 96
hudsonica, 346
maydelliana, 346
maydelliana ssp. *melanocephala*, 96
varians, 96
Oxyura jamaicensis, 378, 483
Ozoga, J. J., 366
Ozoga, J. J., R. V. Doepker and R. D. Earle. Hunter-harvest of Captive-raised Male White-tailed Deer, *Odocoileus virginianus*, Released in Upper Michigan, 357

Paddlefish, 3
Paintbrush, Indian, 97
Purple, 346
Thompson's, 329
Panama, Venezuela, and Mexico, Organochlorine Contaminants in Migrant and Resident Prey of Peregrine Falcons, *Falco peregrinus*, in, 493
Pandion haliaetus, 361, 436
Pandion haliaetus, banded in Canada up to 1989, Recovery Patterns of Ospreys, 361
Panicum sp., 311
perlongum, 82
praecocius, 82
xanthophysum, 80
Pantosteus jordani, 27
Papaver cornwallisensis, 90
keelei, 94
macounii, 90
radicatum, 345
Parelaphostrongylus tenius, 116
Parfenov, P., 534
Parker, C. R., reviews by, 155, 278, 287
Parmelia omphalodes, 109
sulcata, 109
Parmeliella tryptophylla, 109
Parmeliopsis ambigua, 109
Parnassia kotzebuei, 95, 345
palustris var. *neogaea*, 95, 345
Parrya arctica, 95
Parsley, Large-fruit Desert, 333
Partridge, Gray, 211
Parus atricapillus, 211, 500
Passer domesticus, 211, 500
Passerculus sandwichensis, 211
Patterson, R. T., 454
Pedicularis arctica, 97
capitata, 97, 346
flammea, 90, 346
labradorica, 346
lanata, 97, 346
lapponica, 346
sudetica, 97, 346
Pelecanus erythrorhynchos, 483
Pelican, American White, 483
Peltigera aphthosa, 109
canina, 109
didactyla, 109
lepidophora, 109
malacea, 109
neckeri, 109
polydactyla, 109
ponojensis, 109
rufescens, 109
scabrosa, 109
Penstemon fruticosus, 333
Penstemon, Shrubby, 333
Perca flavescens, 237
Perch, Yellow, 237

Percina copelandi, 4
shumardi, 2
Perdix perdix, 211
Perognathus fasciatus, 313
Peromyscus leucopus, 118
maniculatus, 118, 313
Peromyscus leucopus, Use of Woody Ground Litter as a Substrate for Travel by the White-Footed Mouse, 118
Pertusaria bryontha, 109
coriacea, 109
dactylina, 109
panyrga, 109
Petromyzon marinus, 11
Phacelia hastata, 333
Phacelia, Silverleaf, 333
Phaeophyscia endococcinea, 109
kairamoi, 109
sciastra, 109
Phalacrocorax auritus, 428, 471
Phalarope, Wilson's, 507
Phalaropus tricolor, 507
Phasianus colchicus, 500
Pheasant, Ring-necked, 500
Philadelphus lewisii, 333
Philonotis fontana var. *pumila*, 102
Phleum pratense, 220
Phlox longifolia, 332
richardsonii, 90
Phlox, Long-leaf, 332
Phoca hispida, 3, 226
Phocoena phocoena, 3, 36, 62, 69, 489
Phocoena phocoena, in Canada, Status of the Harbour Porpoise, 36
Phocoena phocoena, near Point Barrow, Alaska, Recent Sightings of Harbour Porpoises, 489
Phocoenoides dalli, 3
Phoxinus cumberlandensis, 237
eos, 237
erythrogaster, 237
neogaeus, 239
Phoxinus eos, Preliminary Evidence for Fractional Spawning by the Northern Redbelly Dace, 237
Phragmites australis, 456
Phyconia detersa, 109
Phyllodoce caerulea, 346
Physcia adscendens, 109
aipolia, 109
caesia, 109
dubia, 109
Physconia muscigena, 109
Physeter catadon, 5
Pica pica, 211, 317
Picea spp., 316
abies, 474
glauca, 319, 348, 366, 436
mariana, 112, 192, 366, 374, 436
rubens, 112
Pickerel, Chain, 4
Grass, 4, 11
Redfin, 4
Picoides pubescens, 500
villosus, 211, 500
Pielou, E. C., reviews by, 160, 168, 294
Pike, Northern, 12
Pilchard, 60
Pimephales notatus, 4, 237
Pine, Jack, 192, 369, 443
Pinyon, 435
Ponderosa, 327
Red, 78, 192, 366, 443, 474
Scotch, 474
White, 366, 443, 474
Yellow, 78
Pinguicula vulgaris, 97
Pinicola enucleator, 500
Pintail, Northern, 471
Pinus banksiana, 192, 369, 443
edulis, 435
ponderosa, 327
resinosa, 78, 192, 366, 443, 474
strobus 87, 100, 105, 366, 443, 474
sylvestris, 474
Piosoma setosum, 312
Pitt, M. D., 327
Plagiochila arctica, 101
Plagiomnium ellipticum, 102
medium, 102
Plantago canescens, 97
juncoides var. *glauca*, 97
major, 219
maritima, 456
maritima ssp. *juncoides*, 97
patagonica, 333
Plantain, Seaside, 97
Planz, J. V. and G. L. Kirkland, Jr. Use of Woody Ground Litter as a Substrate for Travel by the White-Footed Mouse, *Peromyscus leucopus*, 118
Platanthera clavellata, 374
Plectrophenax nivalis, 226
Pleuropogon sabinii, 344
Ploesoma truncatum, 467
Plover, Black-bellied, 211
Collared, 495
Piping, 471
Semipalmated, 471, 495
Pluvialis squatarola, 211
Poa alpigena, 91, 344
alpina, 344
arctica, 91, 344
compressa, 220
flexuosa, 344
glauca, 91, 344
pratensis, 328
sandbergii, 328
Poacher, Cutfin, 25
Pixie, 2, 24
Pricklebreast, 25
Sea, 24
Poacher, *Occella impi*, in Canada, Status of the Pixie, 24
Pocket Mouse, Olive-backed, 313
Podiceps auritus, 484
grisegena, 485
nigricollis, 480
Podiceps nigricollis, in Minnesota, Wetland Selection by Eared Grebes, 480
Podilymbus podiceps, 484
Pogonia ophioglossoides, 374
Pohlia cruda, 102
nutans, 102

Pollan, Irish, 179
Polyarthra euryptera, 467
remata, 467
vulgaris, 467
Polyblastia cupularis, 109
gelatinosa, 109
Polychidium muscicola, 109
Polygala polygama, 80
senega, 80
Polygonum aviculare, 219
convolvulus, 220
lapathifolium, 220
persicaria, 222
viviparum, 93, 344
Polyodon spathula, 3
Polyphemus pediculus, 464
Polysaccammina ipohalina, 467
Polysporina urceolata, 109
Polytrichum alpinum, 101
juniperinum, 101
strictum, 101
Pompholyx sulcata, 467
Pondweed, 31, 90
Filiform, 343
Pontigulasia compressa, 469
Pooecetes gramineus, 211
Poplar, 351
Poppy, 94
Arctic, 345
Populus spp., 181, 366
balsamifera, 316, 351
deltoides, 483
grandidentata, 443
tremuloides, 112, 319, 324, 436, 443
Poronotus triacanthus, 60
Porpidia flavocaerulescens, 110
marocarpa, 110
thomsonii, 110
Porpoise, Dall's, 3
Finless, 43
Harbour, 3, 36, 62, 69, 489
Porpoise, *Phocoena phocoena*, in Canada, Status of the Harbour, 36
Porpoises, *Phocoena phocoena*, near Point Barrow, Alaska, Recent Sightings of Harbour, 489
Portulaca oleracea, 222
Porzana carolina, 214
Posthodiplostomum minimum, 32
Potamocypris unicaudata, 462
Potamogeton sp., 31
filiformis, 90, 343
vaginatus, 90
Potentilla anserina, 456, 508
biflora, 90
egedii, 95, 345
fruticosa, 372
fruticosa ssp. *floribunda*, 95
hyparctica var. *elatior*, 95, 345
nivea, 96
nivea ssp. *hookeriana*, 96
nivea var. *nipharga*, 96
palustris, 96, 345
prostrata ssp. *prostrata*, 96
rubricaulis, 96
vahliana, 96
Potvin, F., L. Breton, L.-P. Rivest, and A. Gingras. Application of a Double-count Aerial Survey Technique for White-tailed Deer, *Odocoileus virginianus*, on Anticosti Island, Québec, 435
Power, G., review by, 286
Powles, P. M., S. Finucan, M. van Haaften, and R. A. Curry. Preliminary Evidence for Fractional Spawning by the Northern Redbelly Dace, *Phoxinus eos*, 237
Prairie Chicken, Greater, 84
Prairie Gentian, Blue, 84
White, 84
Preissia quadrata, 101
Prestrud, P. Food Habits and Observations of the Hunting Behaviour of Arctic Foxes, *Alopex lagopus*, in Svalbard, 225
Prickleback, Blackline, 2
Primrose, Erect, 346
Greenland, 346
Primula egaliksensis, 97, 346
stricta, 97, 346
Prosopis glandulosa, 324
Prosopium coulteri, 4
cylindraceum, 4
Proterorhinus marmoratus, 209
Protoblastenia rupestris, 110
Protoparmelia badia, 110
Prunus pumila, 80
susquehanae, 80
virginiana, 328
Pseudechiniscus sp., 303
suillus, 304
suillus f. *facettalis*, 304
Pseudemys floridana, 241
Pseudephebe minuscula, 110
Pseudolepicoleaceae, 101
Pseudoleskeella tectorum, 102
Pseudophonus, 314
Pseudorca crassidens, 3
Pseudotsuga menziesii, 329
Psora decipiens, 110
himalayana, 110
rubiformis, 110
Psorinia conglomerata, 110
Ptarmigan, 200
Rock, 203, 225
Ptilidium ciliare, 101
Puccinellia andersonii, 91
angustata, 90
borealis, 92
deschampsioides, 92, 344
langeana, 92, 344
nuttalliana, 456
phryganodes, 92, 344
vaginata, 92
Puccoon, Columbia, 332
Puffin, 226
Atlantic, 429
Puffinus griseus, 56
Pungitius pungitius, 125
Pussytoes, Alpine, 346
Pycnanthemum lanceolatum, 80
virginianum, 80
Pygmyflower, Northern, 346
Pylodictis olivaris, 4

Pyrenopsidium granuliforme, 110
Pyrola grandiflora, 96, 346
rotundifolia, 80
secunda, 96

Québec, Application of a Double-count Aerial Survey Technique for White-tailed, Deer, *Odocoileus virginianus*, on Anticosti Island, 435
Québec, Discovery of a Living 900 Year-old Northern White Cedar, *Thuja occidentalis*, in Northwestern, 192
Québec, 1979 to 1989, Distribution, Abundance, and Changes of Seabird Populations of the Gaspé Peninsula, 427
Queenfish, 237
Quercus spp., 474
alba, 80, 443, 475
macrocarpa, 80
prinus, 118, 475
rubra, 443, 475
velutina, 80, 118
Quiscalus quiscala, 211, 500

Rabbit-brush, Common, 329
Racomitrium lanuginosum, 103
Ragwort, Marsh, 346
Rangifer tarandus, 225
tarandus platyrhynchus, 226
Rankin Inlet, District of Keewatin, Northwest Territories, The Vascular Plant Flora of, 342
Ranunculus acris, 219
aquatilis, 94
aquatilis var. *subrigidus*, 345
cymbalaria, 94, 345, 456
gmelinii, 94, 345
hyperboreus, 94, 345
nivalis, 94
pallasii, 345
pedatifidus, 94
pedatifidus var. *leiocarpus*, 345
pygmaeus, 94
rhomboideus, 80
Rattle, Purple, 346
Rattlesnake, 118
Raven, Common, 500
Razorbill, 429
Recurvirostra americana, 471, 507
Recurvirostra americana, Breeding Records in the Northwest Territories, with Notes on Avocet Parasitism of Mew Gull, *Larus canus*, Nests, Recent American Avocet, 507
Redhead, 378
Redhorse, Black, 2
Copper, 3
Golden, 2, 17
River, 2, 17
Shorthead, 17
Redpoll, Common, 500
Reebs, S., reviews by, 284, 408, 412
Reed-Bentgrass, 343
Reedgrass, Purple, 91
Reimchen, T. E. Extended Longevity in a Large-bodied Stickleback, *Gasterosteus*, Population, 122
Reindeer, 225
Svalbard, 225
Rheum rhaponticum, 219
Rhinichthys cataractae smithi, 3
cataractae spp., 5
falcatus, 2
osculus, 2
umatilla, 2
Rhizocarpon alpicola, 110
chioneum, 109
ferax, 110
geminatum, 110
geographicum, 110
hochstetteri, 110
superficiale, 110
Rhizoplaca chrysoleuca, 110
melanopthalma, 110
Rhododendron lapponicum, 96, 346
Rhus aromatica, 80
glabra, 329
Rhynchospora alba, 374, 536
Ribes cereum, 329
Riez, A. E., 493
Rinodina archaea, 110
bischoffii, 110
lyngei, 110
roscida, 110
turfacea, 110
Rissa tridactyla, 56, 226, 429
Ritchie, R. J. and R. E. Ambrose. The Status of Selected Birds in East-central Alaska, 316
Rivest, L.-P., 435
Robin, American, 211, 500
Rock-Cress, Alpine, 94
Arctic, 345
Holboell's, 332
Rock-Jasmine, 97
Rocket, Small-flowered, 95
Rosa spp., 185
carolina, 80
humilis, 80
lucida, 80
nitida, 375
nutkana, 333
virginiana, 80
Rose, 185
Nootka, 333
Rose-bay, Lapland, 96, 346
Rubus chamaemorus, 345
Rudbeckia hirta, 80
Rudd, 206
Rudd, *Scardinius erythrophthalmus*, and Notes on the Introduced Round Goby, *Neogobius melanostomus*, First Record for Canada of the, 206
Rumex arcticus, 93
Rush, Arctic, 344
Chestnut, 344
Two-glumed, 344
White, 344
Rye, Wild, 185

Sage, Pasture, 328
Sagebrush, 319
Big, 327
Salamander, Marbled, 196
Tiger, 312
Salamander, *Ambystoma opacum*, on Kelleys Island, Lake

Erie, Electrophoretic Identification of the Marbled, 196
Salicornia rubra, 456
Salix spp., 181, 325, 350
alaxensis, 93, 344
amygdaloides, 483
arctica, 93, 344
arctophila, 344
brachycarpa ssp. *niphoclada*, 93
exigua, 483
farrae, 93
fullertonensis, 344
fuscescens, 344
glauca, 93
hastata, 90
herbacea, 344
humilis, 80
lanata, 343
lanata ssp. *calcicola*, 344
lanata ssp. *richardsonii*, 93, 344
phlebophylla, 90
planifolia, 93, 344, 350
polaris, 93
reticulata, 93, 344
Salmo salar, 4
trutta, 17, 32
Salmon, Atlantic, 4
Chinook, 46
Salvelinus alpinus spp., 4
confluentus, 4
fontinalis, 17, 32
fontinalis timagamiensis, 3
namaycush, 237
Sanderling, 495
Sandlance, 433
Sandpiper, Baird's, 471
Least, 471, 494
Lesser, 496
Pectoral, 471
Purple, 226, 380
Semipalmated, 471, 494
Solitary, 495
Spotted, 494
Upland, 318
Western, 494
Sandwort, Boreal, 345
Low, 345
Northern, 94
Sardina pilchardus, 60
Sardine, Pacific, 2
Sardinops sagax, 2
Sarracenia purpurea, 374
Saskatchewan, Range Extension for the Plains Spadefoot, *Scaphiopus bombifrons*, Inferred from Owl Pellets Found near Outlook, 311
Saskatchewan: Urbanization and short-term population trends, Comparison between urban and rural bird communities in prairie, 210
Saskatoon, 185
Saxifraga aizoides, 95, 345
caespitosa, 95, 343
caespitosa ssp. *caespitosa*, 345
caespitosa ssp. *exaratoides*, 345
cernua, 95, 345
foliolosa, 95
hirculus, 95
hirculus var. *propinqua*, 345
nivalis, 95
oppositifolia, 95, 345
rivularis, 95, 345
tenuis, 345
tricuspidata, 95, 345
virginiensis, 80
Saxifrage, Alpine, 95
Brook, 95, 345
Golden, 95
Nodding, 95, 345
Prickly, 95
Purple, 95, 345
Slender Arctic, 345
Three-toothed, 345
Tufted, 95, 343
Yellow Marsh, 95, 345
Yellow Mountain, 95, 345
Scapania simmonsii, 101
Scaphiopus bombifrons, 311
Scaphiopus bombifrons, Inferred from Owl Pellets Found near Outlook, Saskatchewan, Range Extension for the Plains Spadefoot, 311
Scardinius erythrophthalmus, 206
Scardinius erythrophthalmus, and Notes on the Introduced Round Goby, *Neogobius melanostomus*, First Record for Canada of the Rudd, 206
Scaup, Greater, 378
Lesser, 378
Schaereria tenebrosa, 110
Schellenberg, M. P., reviews by, 167, 295, 297
Schistidium andreaeopsis, 103
apocarpum, 103
holmenianum, 103
rivulare, 103
tenerum, 103
Schizachyrium scoparium, 80
Schizaea pusilla, 372
Schizaea pusilla, Curly-Grass Fern, an Addition to the Flora of New Brunswick, 372
Scirpus sp., 508
caespitosus, 536
caespitosus ssp. *austriacus*, 92, 344
caespitosus var. *callosus*, 374
paludosus, 456
Scleranthus annuus, 222
Scomber scombrus, 60
Scorpidium scorpioides, 103, 304
turgescens, 103
Scoter, Black, 378
Surf, 378
White-winged, 378
Scott, P.A., R. J. Staniforth and D. C. F. Fayle. Re-examination of a Water Birch, *Betula occidentalis*, Outlier of the Northwestern Hudson Bay Lowlands, 348
Scotter, G. W., 87, 105
Scotter, G. W. and D. H. Vitt. Bryophytes of the Melville Hills Region, Northwest Territories, 100
Scouring-Rush, Dwarf, 90
Sculpin, Cultus Pygmy Coastrange, 5
Deepwater, 2
Fourhorn, 2
Mottled, 5
Shorthead, 3

Spinynose, 5
Spoonhead, 2
Scurvy-Grass, 94, 345
Sea-Blite, 93
Sea Lion, California, 3
Steller, 3
Sea-thrift, Labrador, 346
Seabeach-Sandwort, 94, 345
Seal, Bearded, 226
Hooded, 3
Northern Elephant, 3
Ringed, 3, 226
Sedge, 92
Bear-like, 344
Bubble, 344
Clustered, 344
Dark-brown, 344
Fragile-seeded, 344
Hair-like, 344
Liddon's, 333
Nodding, 344
Rock, 344
Rocky-ground, 344
Rush-like, 344
Scant, 344
Seaside, 344
Sheathed, 344
Stiff, 344
Upright Water, 344
Water, 344
Wide-bracted Salt, 344
Sedum spurium, 219
Selaginella rupestris, 80
Semotilus atromaculatus, 237
Senecio atropurpureus, 98
congestus, 346
hyperborealis, 98
lugens, 98
vulgaris, 219
Sepia sp., 60
Sepiola sp. , 60
Seriphus politus, 60, 237
Serviceberry, 328
Setaria viridis, 222
Shearwater, Corey's, 56
Sooty, 56
Sheep, California Bighorn, 327
Rocky Mountain Bighorn, 331
Sheep, *Ovis canadensis californiana*, in British Columbia: Assessing Optimal Foraging Habitat, Diet of California Bighorn, 327
Sheperdia argentea, 325
canadensis, 96
Shiner, Bigmouth, 2
Blackchin, 4
Common, 16
Ghost, 4
Golden, 206
Pugnose, 2
Redfin, 2
Roseyface, 4
Satinfin, 237
Silver, 2
Striped, 4
Weed, 4
Shoveler, Northern, 183
Shrike, Loggerhead, 211, 321
Shrike, *Lanius ludovicianus*, Population, Habitat Change as a Factor in the Decline of the Western Canadian Loggerhead, 321
Sialia currucoides, 319
Silene acaulis, 94
acaulis ssp. *acaulis*, 345
involucrata, 94
noctiflora, 222, 333
pratensis, 222
uralensis, 94
Silene, Night-flowering, 333
Silverside, 237
Brook, 2
Silverweed, 508
Northern, 345
Sinapis arvensis, 219
Siskin, Pine, 500
Sisymbrium altissimum, 219, 333
Sitta canadensis, 211
carolinensis, 500
Skua, 230
Smelt, Pygmy, 4
Pygmy Longfin, 5
Rainbow, 490
Smilacina trifolia, 374
Smith, D. G., 474
Snake, Blue Racer, 84
Snow-Buttercup, 94
Snowberry, Common, 328
Western, 185
Soapberry, 96
Sodhi, N. S. Comparison between urban and rural bird communities in prairie Saskatchewan: Urbanization and short-term population trends, 210
Solidago sp., 312, 456
multiradiata, 98
ptarmicoides, 82
rigida, 82
uliginosa, 375, 536
Solitaire, Townsend's, 316
Solorina bispora, 110
saccata, 110
Somateria mollissima, 226, 429
spectabilis, 378
Sonchus arvensis, 219, 456
asper, 222
oleraceus, 222
Sora, 214
Sorghastrum nutans, 80
Sorghum nutans, 82
Sorrel, Mountain, 93, 344
Spadefoot, Plains, 311
Spadefoot, *Scaphiopus bombifrons*, Inferred from Owl Pellets Found near Outlook, Saskatchewan, Range Extension for the Plains, 311
Sparganium hyperboreum, 90
Sparrow, American Tree, 500
Baird's, 211
Chipping, 211
Clay-colored, 211
House, 211, 499
Savannah, 211
Vesper, 211

White-throated, 211
Spartina gracilis, 456
Speiser, R., 474
Spergula arvensis, 222
Spergularia marina, 456
Spermophitus, 313
Speyeria idalia, 84
Sphaerophorus fragilis, 110
globosus, 110
Sphagnum capillifolium, 101
cuspidatum, 536
flavicomans, 536
fuscum, 536
magellanicum, 536
pulchrum, 536
rubellum, 536
russowii, 101
tenellum, 536
teres, 101
Sphinx gordius, 312
Spider, Jumping, 466
Wolf, 466
Spinacia oleracea, 219
Spirinichus thaleichthys, 5
Spizella arborea, 500
pallida, 211
passerina, 211
Splachnum sphaericum, 101
vasculosum, 101
Sporastatia polyspora, 110
testudinea, 110
Sporobolus heterolepis, 82
Spruce, 316
Black, 192, 366, 436
Norway, 474
Red, 112
White, 319, 348, 366, 436
Squid, Common, 60, 68
Squirrel, Red, 317
Stabb, M., review by, 543
Stagnicola elodes, 467
Staniforth, R. J., 348
Star, Sticky Shooting, 333
Starling, European, 380, 499
Starwort, Bright, 345
Edward's, 345
Long-stalked, 94, 345
Low, 345
Status of the Atlantic White-sided Dolphin, *Lagenorhynchus acutus*, in Canada, 64
Status of the Chestnut Lamprey, *Ichthyomyzon castaneus*, in Canada, 14
Status of the Common Dolphin, *Delphinus delphis*, in Canada, 55
Status of the Harbour Porpoise, *Phocoena phocoena*, in Canada, 36
Status of the Mountain Sucker, *Catostomus platyrhynchus*, in Canada, 27
Status of the Northern Brook Lamprey, *Ichthyomyzon fossor*, in Canada, 7
Status of the Pixie Poacher, *Occella impi*, in Canada, 24
Status of the Y-Prickleback, *Allolumpenus hypochromus*, in Canada, 19
Status Reports VIII, Rare and Endangered Fishes and Marine Mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee, 1
Staurothele drummondii, 110
Stellaria edwardsii, 345
humifusa, 94, 345
laeta, 94, 345
longifolia, 456
longipes, 94
media, 220
monantha, 94, 345
Stellerina xyosterna, 25
Stenella attenuata, 56
coeruleoalba, 5
longirostris
Stercorarius pomarinus, 318
skua, 230
Stereocaulon arcticum, 110
botryosum, 110
paschale, 110
Sterna caspia, 318
forsteri, 471
hirundo, 429, 510
Stickleback, Enos Lake, 3
Giant, 2
Large-bodied, 122
Texada, 5
Threespine, 122
Unarmoured, 2
Stickleback, *Gasterosteus*, Population, Extended Longevity in a Large-bodied, 122
Stipa spp., 185
comata, 327
Stizostedion vitreum glaucum, 3
Stoneroller, Central, 2
Storm-Petrel, Leach's, 427
Sturgeon, Atlantic, 4
Green, 2
Lake, 2
Shortnose, 2
White, 2
Sturnella magna, 495
neglecta, 211
Sturnus vulgaris, 380, 500
Suaeda calceoliformis, 93
depressa, 456
Sucker, Jasper Longnose, 4
Longnose, 30
Mountain, 2, 27
Northern Mountain, 27
Plains, 27
Salish, 3
Spotted, 2
Tahoe, 32
Utah, 32
White, 17, 30
Sucker, *Catostomus platyrhynchus*, in Canada, Status of the Mountain, 27
Sula bassana, 56
bassanus, 427
Sullivan, B. D. and J. J. Dinsmore. Home Range and Foraging Habitat of American Crows, *Corvus brachyrhynchos*, in a Waterfowl Breeding Area in Manitoba, 181
Sumac, 329
Sundew, Thread-Leaved, 534
Sundew, *Drosera filiformis* in Nova Scotia: An Assessment

of Risks of a Proposal to Mine Fuel Peat from its Habitat, The Thread-leaved, 534
Sunfish, Green, 2, 17
Longear, 2
Orangespotted, 2
Redbreast, 2
Susan, Brown-eyed, 332
Suydam, R. S. and J. C. George. Recent Sightings of Harbour Porpoises, *Phocoena phocoena*, near Point Barrow, Alaska, 489
Svalbard, Food Habits and Observations of the Hunting Behaviour of Arctic Foxes, *Alopex lagopus*, in, 225
Swallow, Barn, 211, 494
Cliff, 494
Tree, 211
Symphoricarpos albus, 328
occidentalis, 185
Synchaeta pectinata, 467
stylata, 467

Tachycineta bicolor, 211
Tamarack, 112, 366
Tamiasciurus hudsonicus, 317
Tanacetum vulgare, 221
Taraxacum alaskanum, 98
dumetorum, 98
erythrospermum, 221
lacerum, 346
officinale, 219
pumilum, 98
Tardigrada of the Canadian High-Arctic 1. Freshwater Tardigrades from Devon Island, Northwest Territories, Contributions to the, 303
Teal, Blue-winged, 494
Telfer, E. S. Habitat Change as a Factor in the Decline of the Western Canadian Loggerhead Shrike, *Lanius ludovicianus*, Population, 321
Teloschistes arcticus, 110
Tern, Black, 471, 483
Caspian, 318
Common, 429, 510
Forster's, 471
Testudinella elliptica, 467
Tetraplodon mnioides, 101
pallidus, 102
paradoxus, 102
Thamnolia subuliformis, 110
vermicularis, 110
Thlaspi arvense, 220
Thompson, I. D., review by, 296
Thomson, J.W. and G.W. Scotter. Lichens of the Cape Parry and Melville Hills Regions, Northwest Territories, 105
Thrasher, Brown, 211, 316
Thrombium epigaeum, 110
Thrush, Grey, 230
Swainson's, 211
Thuidium abietinum, 102
recognitum, 102
Thuja occidentalis, 112, 192, 366, 372
Thuja occidentalis, in Northwestern Québec, Discovery of a Living 900 Year-old Northern White Cedar, 192
Thunnus albacares, 56
thynnus, 5
Timmia megapolitana ssp. *bavarica*, 102
norvegica, 102
sibirica, 102
Toad-flax, Bastard, 333
Tofieldia coccinea, 93, 344
pusilla, 93, 344
Tokaryk, T. T., reviews by 418, 420, 422, 423
Tomenthypnum, 100
nitens, 103
Toninia caeruleonigricans, 110
lobulata, 110
Topminnow, Blackstripe, 2
Topping, J., 272
Tortula norvegica, 103
ruralis, 103
Toxostoma rufum, 211, 316
Trachemys scripta, 241
scripta elegans, 246
Trachurus trachurus, 60
Tragopogon dubius, 334
major, 221
Trematode, 32
Tremolecia atrata, 110
Trichocerca rousseleti, 467
Trichocorixa verticalis interiores, 466
Trichotria tetractis, 467
Trifolium hybridum, 221
pratense, 219
repens, 219
stoloniferum, 80
Triglochin maritima, 456, 508
maritimum, 91
palustre, 91
Tringa flavipes, 471, 494
melanoleuca, 471, 495
solitaria, 495
Trionyx muticus, 241
Trisetum spicatum, 92, 344
Trisetum, Spike, 344
Triticum sp., 311
Tritomaria quinquedentata, 101
Trochammina macrescens, 454
Troglodytes aedon, 211
Trout, Aurora, 3
Brook, 17, 32
Brown, 17, 32
Bull, 4
Lake, 237
Rainbow, 11, 17, 32
Tsuga canadensis, 366, 474
Tuckermannopsis pinastri, 110
Tuininga, K., 206
Tumblemustard, 333
Tuna, Bluefin, 5
Yellow-fin, 56
Turdus migratorius, 211, 500
pilaris, 230
Turnstone, Ruddy, 318, 495
Tursiops truncatus, 5, 70
Turtle, 241
Kefts River, 241
Ouachita Map, 241
Painted, 241
Slider, 241
Snapping, 241

Turtles, *Chelydra serpentina* and *Chrysemys picta*, Ontogenetic changes in habitat use by juvenile, 241
Tympanuchus cupido, 84
phasianellus, 185
Tympanuchus phasianellus, in the Interlake Region of Manitoba, Effects of Aspen Succession on Sharp-tailed Grouse, 185
Typha latifolia, 319, 456
Tyrannus tyrannus, 211, 318

Ulmus americana, 366
Umbilicaria arctica, 110
havasii, 110
hyperborea, 110
proboscidea, 110
torrefacta, 110
virginis, 110
Uria spp., 228
aalge, 226, 429
lomvia, 226
Ursus maritimus, 226
Usnea compacta, 111
glabrescens, 111
lapponica, 111
substerilis, 111
Utricularia cornuta, 375

Vaccinium sp., 118
corymbosum, 80
macrocarpon, 375, 536
oxycoccus, 375, 536
uliginosum, 97, 346
vitis-idaea var. *minus*, 97, 346
Van Haaften, M., 237
Van Rompu, E. A., W. H. De Smet and L. Beyens. Contributions to the Tardigrada of the Canadian High-Arctic 1. Freshwater Tardigrades from Devon Island, Northwest Territories, 303
Vanellus chilensis, 495
Vardy, C., 272
Venezuela, and Mexico, Organochlorine Contaminants in Migrant and Resident Prey of Peregrine Falcons, *Falco peregrinus*, in Panama, 493
Veronica longifolia, 219
Verrucaria arctica, 111
cataleptoides, 111
deversa, 111
muralis, 111
ossiseda, 111
Vicia cracca, 219
Viola pedata, 82
pedatifida, 82
sagittata, 80
Vireo olivaceus, 211
Vireo, Red-eyed, 211
Vitt, D. H., 100
Voitia hyperborea, 102
Vole, 226
Voles, Meadow, 313
Vulpes vulpes, 200, 234
Vulpes vulpes, as Biological Control Agents for Introduced Arctic Foxes, *Alopex lagopus*, on Alaskan Islands, Red Foxes, 200
Vulture, Turkey, 316

Waiser, W. A., reviews by, 168, 297, 550, 551
Walleye, Blue, 3
Walrus, Atlantic, 3
Warbler, Blackburnian, 366
Magnolia, 319
Yellow, 211
Warbler, *Dendroica fusca*, Breeding Habitat in Upper Michigan, Characteristics of Blackburnian, 366
Warmouth, 4
Warty, 25
Water-Buttercup, White, 94, 345
Water-Crowfoot, Small Yellow, 345
Water-Milfoil, Northern Spiked, 346
Waxwing, Bohemian, 500
Cedar, 211
Weevil, 311
Wein, G., 216
Wein, R. W., G. Wein, S. Bahret and W J. Cody. Northward Invading Non-native Vascular Plant Species in and Adjacent to Wood Buffalo National Park, Canada, 216
Whale, Baird's Beaked, 5
Beluga, 5
Blainville's Beaked, 3
Blue, 3
Bowhead, 3
Cuvier's Beaked, 3
Dwarf Sperm, 5
False Killer, 3
Fin, 3, 70
Grey, 3
Hubb's Beaked, 3
Humpback, 3
Killer, 5
Long-finned Pilot, 5
Minke, 5
Northern Bottlenose, 5
Northern Right, 3
Pygmy Sperm, 5
Right, 3
Sei, 5
Short-finned Pilot, 5
Sowerby's Beaked, 3
Sperm, 5
Stejneger's Beaked, 3
True's Beaked, 3
White, 39
Wheatgrass, 185
Bluebunch, 327
Whiskers, Old Man's, 332
Whitefish, Acadian, 3
Humpback, 490
Lake, 4
Lake Simcoe, 2
Mira, 4
Opeongo, 4
Pygmy, 4
Round, 4
Squanga, 2
Whiting, 60
Blue, 60, 68
Whitlow-Grass, 342
Alpine, 345
Austrian, 345
Milky, 345
Smooth, 345
Snow, 345

Wikeem, B. M. and M. D. Pitt. Diet of California Bighorn Sheep, *Ovis canadensis californiana*, in British Columbia: Assessing Optimal Foraging Habitat, 327
Willet, 211, 494
Willow, 93, 181, 325
Alaska, 344
Alaska Bog, 344
Arctic, 344
Dwarf, 80
Flat-leaved, 344
Fullerton's, 344
Least, 344
Lime-loving Wooly, 344
Net-veined, 344
Peach-leaved, 483
Richardson's, 344
Sandbar, 483
Trailing, 344
Wooly, 343
Willow-Herb, Broad-leaved, 96, 346
Marsh, 346
Wintergreen, Large-flowered, 96, 346
One-sided, 96
Wolf, 201
Wolffish, Bering, 2
Wood Buffalo National Park, Canada, Northward Invading Non-native Vascular Plant Species in and Adjacent to, 216
Wood-Rush, Arctic, 344
Mountain, 344
Northern, 344
Rush, 93
Woodpecker, Downy, 500
Hairy, 211, 500
Woodsia alpina, 343
glabella, 90, 343
Woodsia, Northern, 343
Smooth, 90, 343
Wormington, A. and J. H. Leach. Concentrations of Migrant Diving Ducks at Point Pelee National Park, Ontario, in Response to Invasion of Zebra Mussels, *Dreissena polymorpha*, 376
Wormwood, 98
Northern, 346
Wren, House, 211
Wuerthner, G., review by, 281

Xanthocephalus xanthocephalus, 211
Xanthoria candelaria, 111
elegans, 111
sorediata, 111
Xeneretmus leiops, 25
Xyris montana, 374

Y-Prickleback, 2, 19
Y-Prickleback, *Allolumpenus hypochromus*, in Canada, Status of the, 19
Yarrow, 334
Yellowlegs, Greater, 471, 494
Lesser, 471, 494
Yellowthroat, Common, 214

Zalophus californianus, 3
Zenaida macroura, 211
Zigadenus venenosus, 333
Ziphius cavirostris, 3
Zoltai, S. C., 87
Zonotrichia albicollis, 211
Zygadenus elegans, 93
Zygonema sp., 536

Index to Book Reviews

Botany
Argus, G. W. and K. M. Pryer. Rare Vascular Plants in Canada: Our Natural Heritage, 291
Bouchard, A., S. Hay, L. Brouillet, M. Jean, and I. Saucier. The Rare Vascular Plants of the Island of Newfoundland, 165
Crum, H. Liverworts and Hornworts of Southern Michigan, 292
Ellis, M. B. and J. P. Fungi Without Gills (Hymenomycetes and Gasteromycetes): An Identification Handbook, 415
Farr, D. F., G. Bills, G. Chamuris, and A. Rossman. Fungi on Plants and Plant Products in the United States, 166
Gleason, H. A. and A. Cronquist. Manual of Vascular Plants of Northeastern United States and Adjacent Canada, 417
Jermy, C. and J. Camus. The Illustrated Field Guide to Ferns and Allied Plants of the British Isles, 417
Isely, D. Vascular Flora of the Southeastern United States: Volume 3, Part 2, Leguminose (Fabaceae), 416
Ownbey, G. B. and T. Morley. Vascular Plants of Minnesota, A Checklist and Atlas, 417
Peattie, D. C. and R. Finch. A Natural History of Trees of Eastern and Central North America, 415
Peattie, D. C. and R. Finch. A Natural History of Western Trees, 415
Phillips, R. Mushrooms of North America, 414
Schofield, J. J. Discovering Wild Plants, Alaska, Western Canada, and the Northwest, 167
Turner, N. J. and A. F. Szczawinski. Common Poisonous Plants and Mushrooms of North America, 418

Environment
Botkin, D. B. Discordant Harmonies: A New Ecology for the Twenty-First Century, 297
Carroll, R. C., J.H. Vandermeer, and P. Rosset. Agroecology: Biological Resource Management, 167
Eldredge, N. The Miner's Canary, 420
Engel, J. R. and J. G. Engel. Ethics of Environment and Development: Global Challenge and International Response, 296
Harington, C. R. Canada's Missing Dimension: Science and History in the Canadian Arctic Islands, 294
Heinrich, B. In a Patch of Fireweed, 421
Jordan, W. R. III, M. E. Gilpin, and J. D. Aber. Restoration Ecology: A Synthetic Approach to Ecological Research, 295
Magurran, A. E. Ecological Diversity and its Measurement, 168
Mighetto, L. Wild Animals and American Environment Ethics, 546
Pielou, E. C. After the Ice Age: The Return of Life to Glaciated North America, 293
Raup, D. M. Extinction, Bad Genes or Bad Luck?, 418

Real, L. A. and J. H. Brown. Foundations of Ecology: Classic Papers with Commentaries, 421
Ross, R. M. and W. D. Allmon. Causes of Evolution: A Paleontological Perspective, 420
Shafer, C. L. Nature Reserves: Island Theory and Conservation Practice, 547
Shepard, P. Man in the Landscape; a Historic View of the Esthetics of Nature, 295
Statistics Canada. Human Activity and the Environment 1991, 419

Miscellaneous
Ainley, M. G. Despite the Odds: Essays on Canadian Women and Science, 168
Bernbaum, E. Sacred Mountains of the World, 169
Bodry-Sanders, P. Carle Akeley: Africa's Collector, Africa's Savior, 298
Bonta, M. M. Women in the Field: America's Pioneering Women Naturalists, 548
Corley-Smith, P. White Bears and Other Curiosities: The First One Hundred Years of the Royal British Columbia Museum, 551
Croker, R. A. Pioneer Ecologist: The Life and Work of Victor Ernest Shelford 1877_1968, 422
Crowcroft, P. Elton's Ecologists:A History of the Bureau of Animal Population, 297
Flader, S. L. and J. B. Callicott. The River of the Mother of God and Other Essays by Aldo Leopold, 550
Fortey, R. Fossils: The Key to the Past, 422
Heuss, T. Anton Dohrn: A Life for Science, 550
Jones, J. O. The U.S. Outdoor Atlas & Recreation Guide, 551
Marks, R. L. Three Men of the Beagle, 423
Nitecki, M. H. Evolutionary Innovations, 552
Smallman, B. N., H. M. Good, and A. S. West. Queen's Biology: An Academic History of Innocence Lost and Fame Gained 1858-1965, 549

Young Naturalists
Batulla, B. Invertebrates, 170
Hiller, I. Introducing Mammals to Young Naturalists, 170

Zoology
Albert, B. Sharks and Whales, 164
Anton, T. Sharks, Sharks, Sharks, 164
Bekoff, M. and D. Jamieson. Interpretation and Explanation in the Study of Animal Behavior, 157
Bergman, C. Wild Echos: Encounters with the Most Endangered Animals in North America, 283
Birkhead, T. The Magpies: The Ecology and Behaviour of Black-billed and Yellow-billed Magpies, 408
Bonner, W. N. The Natural History of Seals, 160
Boyce, M. S. The Jackson Hole Elk Herd: Intensive Wildlife Management in North America, 281
Brazil, M. A. The Birds of Japan, 291
Brooks, D. R. and D. A. McLennan. Phylogeny, Ecology, and Behavior, 279
Brusca, R. C. and Gary J. Brusca. Invertebrates, 158
Bub, H. Bird Trapping and Bird Banding: A Handbook for Trapping Methods All Over the World, 412
Caire, W., J. D. Tyler, B. P. Glass, and M. A. Mares. Mammals of Oklahoma, 160
Campbell, E. C., R. W. Campbell, and R. T. McLaughlin. Waterbirds of the Strait of Georgia, 290
Catton, C. Pandas, 159
Christie, D. Moosebirds and Sandpeeps: Birds in and Around Fundy National Park, 289
Chu, K., C. Clark, P. Tyack, A. R. Emery, and C. Hopkins. The Secret World of Animals: Under the Water, 413
Chubb, K. The Avian Ark: Tales from a Wild Bird Hospital, 546
Clutton-Brock, T. H. The Evolution of Parental Care, 279
Conant, R., R. C. Stebbins, and J. T. Collins. Peterson First Guide to Reptiles and Amphibians, 545
Croxall, J. P. Seabird Status and Conservation: A Supplement, 162
Dekker, D. Prairiewater: Watchable Wildlife at Beaverhills Lake, Alberta, 154
Emmons, L. H. Neotropical Rainforest Mammals: A Field Guide, 156
Galati, R. Golden-crowned Kinglets: Treetop Nesters of the North Woods, 284
Geist, V. and M. H. Francis. Mule Deer Country, 543
Gibbons, J. W. Life History and Ecology of the Slider Turtle, 163
Goodwin, C. The Traveling Birder: 20 Five-star Birding Vacations, 289
Gorman, M. L. and R. D. Stone. The Natural History of Moles, 543
Greer, A. E. The Biology and Evolution of Australian Lizards, 163
Groot, C. and L. Margolis. Pacific Salmon Life Histories, 286
Guthrie, R. D. Frozen Fauna of the Mammoth Steppe: The Story of Blue Babe, 282
Heinrich, B. Ravens in Winter, 412
Inskipp, C. & T. A Guide to the Birds of Nepal, 288
Johnsgard, P. A. Crane Music, 411
Kirkland, G. L. Jr. and J. N. Layne. Advances in the Study of Peromyscus (Rodentia), 409
Kitchener, A. The Natural History of the Wild Cats, 282
Lockley, R. Birds and Islands:Travels in Wild Places, 413
McIntyre, R. Grizzly Cub: Five Years in the Life of a Bear, 280
Murray, J. A. The Great Bear: Contemporary Writings on the Grizzly, 544
Page, J. ZOO The Modern Ark, 408
Parker, S. T. and K. R. Gibson. "Language" and Intelligence in Monkeys and Apes: Comparative Developmental Perspectives, 285
Peckarsky, B. L., P. R. Fraissinet, M. A. Penton, and D. J. Conklin, Jr. Freshwater Macroinvertebrates of Northeastern North America, 155
Rosenberg, K. V., R. D. Ohmart, W. C. Hunter, and B. W. Anderson. Birds of the Lower Colorado, 410
Scotter, G. W., T. J. Ulrich, and E. T. Jones. Birds of the Canadian Rockies, 153
Sergeant, D. E. Harp Seal, Man, and Ice, 288
Stehr, F W. Immature Insects, Volume 2, 287
Stroud, D. A., G. P. Mudge, and M. W. Pienkowski. Protecting Internationally Important Bird Sites: A Review of the EEC Special Protection Area Network in Great Britain, 161
Thorp, J. H. and A. P. Covich. Ecology and Classification of North American Freshwater Invertebrates, 278
Tulloch, B. Migrations: Travels of a Naturalist, 414
Waldon, B. A Guide to Feeding Winter Birds in Ontario, 545
Walton, R. K. and R. W. Lawson. Backyard Bird Song, 162
Wenner, A. M. and P.H. Wells. Anatomy of a Controversy: A Question of a "Language" Among Bees, 154

Advice to Contributors

Content

The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

Manuscripts

Please submit, **to the Editor,** in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

Type the manuscript on standard-size paper, if possible use paper with numbered lines, **double-space throughout**, leave generous margins to allow for copy marking, and **number each page**. For Articles and Notes provide a bibliographic strip, an abstract and a list of key words. Generally words should not be abbreviated but use SI symbols for units of measure. Underline only words meant to appear in italics. The names of authors of scientific names should be omitted except in taxonomic manuscripts or other papers involving nomenclatural problems. "Standard" common names (with initial letters capitalized) should be used at least once for all species of higher animals and plants; all should also be identified by scientific name.

The names of journals in the Literature Cited should be written out in full. Unpublished reports should not be cited here but placed in the text or in a separate documents section. Next list the captions for figures (numbered in arabic numerals and typed together on a separate page) and present the tables (each titled, numbered consecutively in arabic numerals, and placed on a separate page). Mark in the margin of the text the places for the figures and tables.

Extensive tabular or other supplementary material not essential to the text, typed neatly and headed by the title of the paper and the author's name and address, should be submitted in duplicate on letter-size paper for the Editor to place in the Depository of Unpublished Data, CISTI, National Research Council of Canada, Ottawa, Canada K1A 0S2. A notation in the published text should state that the material is available, at a nominal charge, from the Depository.

The **Council of Biology Editors Style Manual**, Fourth edition (1978) available from the American Institute of Biological Sciences, and **The Canadian Style: A Guide to Writing and Editing**, Department of the Secretary of State and Dundurn Press Ltd (1985) are recommended as general guides to contributors but check recent issues (particularly in literature cited) for exceptions in journal format. Either "British" or "American" spellings are acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary, Webster's New International Dictionary** and le **Grand Larousse Encyclopédique** are the authorities for spelling.

Illustrations

Photographs should have a glossy finish and show sharp contrasts. Photographic reproduction of line drawings, **no larger than a standard page**, are preferable to large originals. Prepare line drawings with India ink on good quality paper and letter (don't type) descriptive matter. Write author's name, title of paper, and figure number on the lower left corner or on the back of each illustration.

Reviewing Policy

Manuscripts submitted to *The Canadian Field-Naturalist* are normally sent for evaluation to an Associate Editor (who reviews it or asks another qualified person to do so), and at least one other reviewer, who is a specialist in the field, chosen by the Editor. Authors are encouraged to suggest names of suitable referees. Reviewers are asked to give a general appraisal of the manuscript followed by specific comments and constructive recommendations. Almost all manuscripts accepted for publication have undergone revision — sometimes extensive revision and reappraisal. **The Editor makes the final decision** on whether a manuscript is acceptable for publication, and in so doing aims to maintain the scientific quality, content, overall high standards and consistency of style, of the journal.

Special Charges — Please take special note

Authors **must share in the cost of publication** by paying $70 for each page in excess of five journal pages, plus $7 for each illustration (any size up to a full page), and up to $70 per page for tables (depending on size). Reproduction of color photos is extremely expensive; price quotations may be obtained from the Business Manager. Reprint order forms are included when galley proofs are sent to authors. If grant or institutional funds are available, we ask authors to defray a higher proportion of the cost of publishing, $70 per page for all published pages. Government institutions are expected to pay the full cost of publication. Authors must also be charged for their changes in proofs.

Limited journal funds are available to help offset publication charges to authors with minimal financial resources. Requests for financial assistance should be made to the Business Manager when the manuscript is accepted.

Reprints

An order form for the purchase of reprints will accompany the galley proofs sent to the authors.

FRANCIS R. COOK, Editor
RR 3 North Augusta, Ontario K0G 1R0

Notice of change of address:

The Ottawa Field-Naturalists' Club
Box 35069, Westgate P.O.
Ottawa, Ontario K1Z 1A2

W. J. Cody, Business Manager
The Canadian Field-Naturalist
Box 35069, Westgate P.O.
Ottawa, Ontario K1Z 1A2

The address for the editor remains:

Francis R. Cook, Editor
The Canadian Field-Naturalist
RR 3, North Augusta
Ontario K0G 1R0

4886 027

TABLE OF CONTENTS *(concluded)*

News and Comment

New Honorary Memberships and 1991 Awards of The Ottawa Field-Naturalists' Club 527

Additional proposals for the Revised Constitution of The Ottawa Field-Naturalists' Club — Notice of the 115th Meeting of The Ottawa Field-Naturalists'Club — Call for nominations: The Ottawa Field-Naturalists'Club 1994 Council — Call for nominations: The Ottawa Field-Naturalists' Club 1993 Awards 530

Wolf scientists meet in Edmonton H. DEAN CLUFF 531

The Thread-leaved Sundew, *Drosera filiformis*, in Nova Scotia: An assessment of risks of a proposal to mine fuel peat from its habitat B. FREEDMAN, W. MAASS, and P. PARFENOV 534

Book Reviews

Zoology: Mule Deer Country — The Natural History of Moles — The Great Bear: Contemporary Writings on the Grizzly — Peterson First Guide to Reptiles and Amphibians — A Guide to Feeding Winter Birds in Ontario — The Avian Ark: Tales from a Wild Bird Hospital 543

Environment: Wild Animals and American Environmental Ethics — Nature Reserves: Island Theory and Conservation Practice 546

Miscellaneous: Women in the Field: America's Pioneering Women Naturalists — Queen's Biology: An Academic History of Innocence Lost and Fame Gained 1858-1965 — Anton Dohrn: A Life for Science — The River of the Mother of God and other Essays by Aldo Leopold — White Bears and other Curiosities: The First One Hundred Years of the Royal British Columbia Museum — The U. S. Outdoor Atlas & Recreation Guide — Evolutionary Innovations 548

New Titles 553

Index to Volume 106 Compiled by LESLIE CODY 555

Advice to Contributors 581

Notice of change of addresses: The Ottawa Field-Naturalists' Club and Business Manager, The Canadian Field-Naturalist 582

Mailing date of the previous issue 106(3) : 14 June 1993

Articles

Distribution, abundance, and changes of seabird populations of the Gaspé Peninsula, Québec, 1979 to 1989 GILLES CHAPDELAINE and PIERRE BROUSSEAU 427

Application of a double-count aerial survey technique for White-tailed Deer, *Odocoileus virginianus*, on Anticosti Island, Quebec FRANÇOIS POTVIN, LAURIER BRETON, LOUIS-PAUL RIVEST, and ANDRÉ GINGRAS 435

Responses of breeding Bald Eagles, *Haliaeetus leucocephalus*, to human activities in northcentral Michigan TERYL C. GRUBB, WILLIAM W. BOWERMAN, JOHN P. GIESY, and GARY A. DAWSON 443

The origin, physico-chemistry and biotics of sodium chloride dominated saline waters on the western shore of Lake Winnipegosis, Manitoba W. B. MCKILLOP, R. T. PATTERSON, L. D. DELORME, and T. NOGRADY 454

Nest sites and habitat selected by Cooper's Hawks, *Accipiter cooperii*, in northern New Jersey and southeastern New York THOMAS BOSAKOWSKI, DWIGHT G. SMITH, and ROBERT SPEISER 474

Wetland selection by Eared Grebes, *Podiceps nigricollis*, in Minnesota JANET S. BOE 480

Recent sightings of Harbour Porpoises, *Phocoena phocoena*, near Point Barrow, Alaska ROBERT S. SUYDAM and JOHN CAIGHEAD GEORGE 489

Organochlorine contaminants in migrant and resident prey of Peregrine Falcons, *Falco peregrinus*, in Panama, Venezuela, and Mexico URSULA BANASCH, J. PAUL GOOSSEN, ALBERTO EINSTEIN RIEZ, CLARK CASLER, and ROMEO DOMINGUEZ BARRADAS 493

A ten-year urban winter bird count in Sackville, New Brunswick ANTHONY J. ERSKINE 499

Recent American Avocet, *Recurvirostra americana*, breeding records in the Northwest Territories, with notes on avocet parasitism of Mew Gull, *Larus canus*, nests ERNIE KUYT and BRIAN W. JOHNS 507

Notes

First record of the Rough-legged Hawk, *Buteo lagopus*, from Ellesmere Island, Northwest Territories R. FRANCE and M. SHARP 511

Swim by an Arctic Fox, *Alopex lagopus*, in Alexandra Fiord, Ellesmere Island, Northwest Territories HAROLD STRUB 513

Possible simultaneous rearing of consecutive litters by Black Bears, *Ursus americanus* RANDOLPH J. SEGUIN 514

Metabolism and behavior of wintering Common Map Turtles, *Graptemys geographica*, in Vermont TERRY E. GRAHAM and ANDREW A. GRAHAM 517

Use of a summit mating area by a pair of courting Grizzly Bears, *Ursus arctos*, in Waterton Lakes National Park, Alberta KEITH S. BRADY and DAVID M. HAMER 519

Great Blue Herons, *Ardea herodias*, feeding at a fishing vessel offshore in Lake Erie PETER J. EWINS and BENNETT HENNESSEY 521

Co-operative fishing by Double-crested Cormorants, *Phalacrocorax auritus* EDWARD V. GLANVILLE 522

An adult Cougar, *Felis concolor*, killed by Gray Wolves, *Canis lupus*, in Glacier National Park, Montana DIANE K. BOYD and GRAHAM K. NEALE 524

A Wolf, *Canis lupus*, killed in an avalanche in southwestern Alberta DIANE K. BOYD, LEE B. SECREST, and DANIEL H. PLETSCHER 526

concluded on inside back cover

ISSN 0008-3550

ERNST MAYR LIBRARY
3 2044 114 231 434